

A PC-based stereoscopic video walkthrough

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ABSTRACT

This paper describes a computer program which allows a user to semi-interactively navigate through a pre-recorded environment. The experience is achieved using a set of stereoscopic video sequences which have been recorded while walking around the various pathways of the chosen environment. In the completed system, the stereoscopic video sequences are played back in a sequence such that the operator is given the illusion of being able to continuously and semi-interactively navigate through the environment in stereoscopic 3D. At appropriate decision points (usually intersections) the operator is given the option of choosing which direction to continue moving - thereby providing a level of interactivity. This paper discusses the combination of two recent advances in computer technology to transfer an existing video-disk based stereoscopic video walkthrough to run entirely on a PC. The increased computing power of PCs in recent years has allowed reasonably high-quality video playback to be performed on the desktop PC with no additional hardware. Also, Liquid Crystal Shutter (LCS) glasses systems are now widely available allowing high-quality stereoscopic images to be viewed easily on a PC. The demonstration system we have implemented interfaces with a large range of LCS glasses and allows the exploration of stereoscopic video walkthrough technology.

Keywords: stereoscopic video, walkthrough, surrogate travel, personal computer.

1. INTRODUCTION

This paper discusses a system called a stereoscopic video walkthrough - a system which allows a user to semi-interactively navigate through a pre-recorded environment by playing back appropriate sequences of stereoscopic video. The experience is created by using a stereoscopic video camera to record the various pathways around or through a particular environment. Care must be taken to record sufficient pathways such that the footage can be played in a continuous loop and there are no dead-ends or gaps in alternative pathways. In the completed system the video sequences are played back according to the directions selected by the operator. This gives the operator the illusion of being able to continuously and semi-interactively navigate through the environment.

This project was originally inspired by a Massachusetts Institute of Technology (MIT) project called the Aspen Movie Map ¹ - a surrogate travel experience which allowed a user to navigate the streets of Aspen, Colorado. To make the MIT project possible, a video disk was specially recorded with a compilation of 2D video sequences filmed while driving through the various streets of Aspen. In the completed system the observer was given the impression of being able to interactively navigate through the environment by playing back selected sequences of 2D video from the video disk. At 'decision points' (in this case street intersections) the operator was given the option of choosing which direction to go. The video sequence corresponding to the chosen direction was then played back. A video disk player was used in this project because it was the only accessible technology at the time which allowed the random access playback of stored video, thereby allowing alternate path choices to be played back without significant delay.

The purpose of the Aspen Movie Map was therefore to provide users with the ability to explore Aspen, Colorado without actually going there and hence gain some familiarity with the town. This type of system is best suited to environments in which the number of paths is constrained - e.g. the corridors of a building, the streets of a town or the pathways of an offshore oil rig. Such a system could be used to familiarise a person with a new environment before arrival or allow a person to explore and experience a place without ever going there.

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1.1 THE INITIAL SYSTEM

In 1991, the principle author of this paper developed a simplified experimental system using a video disk player to illustrate the use of stereoscopic video with this technology². The expectation was that stereoscopic display would further increase the realism of the experience. The video disk based system is shown in Figure 1. It consisted of a Macintosh computer running Hypercard software, a video disk player, a specially recorded video disk and a stereoscopic display (in this case a 15" colour TV, LCS glasses and an LCS glasses controller). The video disk was recorded with a series of eight stereoscopic video sequences filmed while walking through various parts of a backyard garden. The computer controlled the video disk player to play the appropriate video sequences in the appropriate order to give the operator the impression of navigating seamlessly through the backyard. The footage included three decision points at which the operator could choose to go in one of two possible directions. A plan view of the paths and video sequences is shown in Figure 2. The decision points are shown in Figures 3 to 5. At decision points the operator used the mouse to select one of the direction arrows on the computer screen. This executed a hypercard script which played the desired video sequence from the video disk player.



Figure 1: Laser disk based stereoscopic video walkthrough

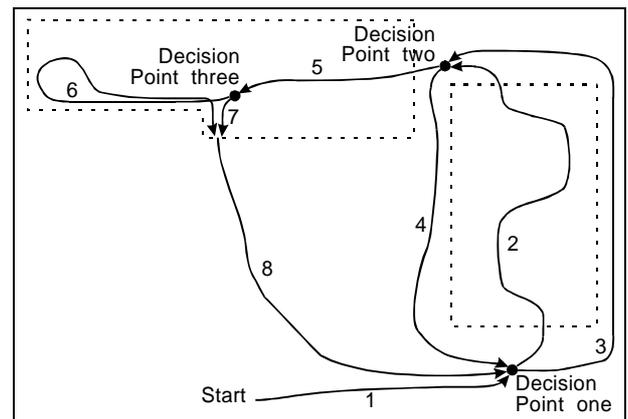


Figure 2: Layout of video sequences used

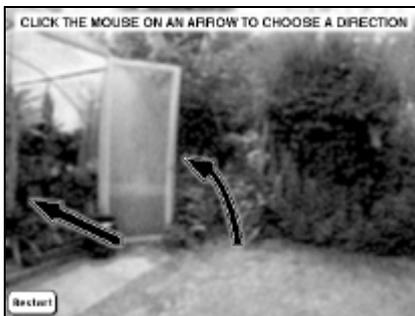


Figure 3: Decision Point 1



Figure 4: Decision Point 2



Figure 5: Decision Point 3

The system worked well and the stereoscopic footage was effective in making the experience more realistic. However, the need to use a video disk and video disk player was seen as a severe limitation to the expanded development and use of such systems. Video disks are expensive to produce and once recorded cannot be modified - therefore an experience could not easily be incrementally developed or modified to correct errors or environment changes. The relatively large amount of equipment and the use of two separate display screens was also seen as a problem. New developments in video playback technology were needed before video walkthrough technology could become realistically accessible.

2. IMPLEMENTATION ON A PC

Recent advances in computer technology have allowed the playback of video on the desktop PC without the need for any special (non-standard) display or compression equipment. In addition, Liquid Crystal Shutter (LCS) glasses systems are now widely available allowing high-quality stereoscopic images to be viewed easily on a PC. These new developments have therefore provided a new platform for the implementation of stereoscopic video walkthroughs.

The goal of the project described in this paper was therefore to implement a stereoscopic video walkthrough on the PC platform which could be used with a wide range of LCS glasses systems and work on a wide variety of PCs running the Windows 95 operating system.

There are several issues which need to be addressed when implementing stereoscopic video playback on a PC. The first issue is interfacing and driving the LCS glasses. LCS glasses work by sequentially blocking alternate eyes as different images are presented on the screen (alternate left and right perspective views - usually at the field-rate of the display). The computer must display different left and right images in the alternate fields displayed on the screen and switch the glasses in synchronisation with those images. The next issue is the storage and playback of compressed stereoscopic video. The video must be stored and played back such that the two views are maintained separate and distinct during the entire process. There is also the issue of which stereoscopic display technique to use - interlaced/field-sequential, page-flipped or over/under. These issues are discussed in more detail in the following sections.

2.1 LCS GLASSES SYSTEMS

As mentioned earlier, there are a wide range of LCS glasses systems available commercially. These systems all have various interfacing characteristics. In order for the project to be more widely accepted, we wanted our program to be able to interface with a wide range of LCS glasses systems. The table below provides a summary of the LCS glasses we had available for testing and their basic interfacing characteristics:

Glasses Manufacturer and Model	Interface Port	Interface Technique
3DTV 3DMagic	Parallel Port	Toggle bits on port
Kasan 3DMax	ISA Card and VGA port	Modify IO registers of ISA Card
NuVision 3D SPEX	Parallel Port	Toggle bits on port
StereoGraphics Simuleyes VR	VGA port	White Line Code
VREX VR Surfer	VGA port	Modify Sync Signal
Woobo Cyberboy	Serial Port	Toggle RTS and DTR bits on port

Table 1: LCS glasses systems and their interfacing characteristics

The systems essentially fall into two groups - those which connect to the VGA port and those which connect to the serial or parallel port. The way in which the glasses connect to the PC make a big difference to how the glasses are driven. LCS glasses systems which connect to the VGA port are able to automatically synchronise with the field-rate of the monitor by reading the video signal. In contrast, LCS glasses systems which connect to the serial or parallel port need to be manually toggled in synchronisation with the field-rate of the display by a software routine running in the PC.

Another important point about these systems is that they can be driven in two different image/video modes to achieve stereoscopic display:

- The page flipping technique involves the allocation of two banks or pages of memory in the video card - one for each of the left and right views. The video card can either display one image or the other. During display, the computer manually switches between the two banks in synchronisation with the display rate of the monitor such that alternate fields or frames on the display are left and right view. Page flipping is normally used with a non-interlaced video mode since it offers full resolution per eye but it can be used with interlaced video modes as well.
- The row-interleaved/interlaced method involves the generation of a single image which contains odd numbered rows from the right image and even numbered rows from the left image - this is called a row-interleaved image[†]. When this type of image is displayed in an interlaced video mode, alternate fields of the display show the left image and right image parts of the row-interleaved image alternately - i.e. a field-sequential display has been effected.

Another display technique called over-under (or above-below) is supported by some LCS systems (e.g. StereoGraphics Crystaleyes GDC3 and Neotek Knowledge Vision) however this mode is not widely supported by currently available LCS glasses systems.

[†] Although the term 'interlaced image' is also commonly used to refer to row-interleaved images, we believe it should be avoided due to possible confusion with the interlaced video mode.

2.2 STEREOSCOPIC VIDEO AND VIDEO COMPRESSION

The three most common formats for storing video sequences on the PC platform are AVI (Audio Video Interleaved), MPEG (Motion Pictures Experts Group) and Apple Quicktime. The problem for this project was how to store the stereoscopic image sequence within the video stream such that the two views are maintained separate through the coding and display stages. The added requirement for this project was that the method should be compatible with existing software and not incur too much extra processing - for reasons of ease of implementation and performance speed. Several different techniques were considered, but the technique which was found to be most suitable for our requirements was the coding of the stereoscopic image sequence in a row-interleaved format. A row-interleaved image has left and right images stored in the odd and even lines of the image respectively (or vice versa). As it turns out, this is very similar to the field-sequential 3D video method used with the PAL and NTSC video standards.

Row-interleaving allows 3D video to be viewed by playing back the video file with a standard video player application while the display is in an interlaced graphics mode - assuming of course that the row-interleaved video sequence has been coded correctly to begin with and the LCS glasses are being switched in synchronisation with the field-rate of the monitor.

Unfortunately, the use of row-interleaved 3D video with video compression does have some problems. It is generally necessary to use some form of compression with video sequences to reduce both the final file size and also the bit-rate of the sequence. There are many different compression techniques available, but they generally all involve lossy compression in order to obtain a reasonable reduction in file size. One often used compression technique is the discrete cosine transform (DCT) as used in the JPEG compression algorithm. The compression technique acts somewhat like a spatial-domain low-pass filter. Unfortunately row-interleaved images usually have a high spatial frequency content due to the alternation between left and right images on alternate lines of the image. If this high-frequency information is filtered out, the left and right images start to become mixed together which results in a form of image ghosting. There are also other compression techniques which can also disrupt 3D content. Most video formats/compressors can be used with row-interleaved 3D video as long as a low compression or uncompressed mode is used - but this can produce very large files. If a high compression ratio is used with an incompatible compression technique, the 3D content of the image sequence can be totally corrupted.

Fortunately, a video compression codec was found which can compress row-interleaved 3D video sequences without significant disruption of the 3D content. The Intel Indeo video codec (version 5)[‡] can achieve quite high compression ratios without losing the stereoscopic nature of the video sequence.

It should be noted that we could have potentially used the MVP (Multiple View Profile) feature of MPEG or a side-by-side format similar to that used in the default Stereoscopic JPEG (JPS) image format³ to store the 3D images in the video stream. However, additional programming would have been needed to interface the playback of the two video streams with the desired display method (e.g. convert side-by-side to row-interleaved, etc).

2.3 SETTING THE VIDEO MODE AND DRIVING THE LCS GLASSES

Two issues remain in the implementation of the stereoscopic video walkthrough: (a) switching the video card into interlaced mode and (b) initialising or driving the LCS glasses.

Switching a video card into interlaced mode requires the modification of a number of a video card's control registers. Unfortunately, the registers which must be changed and the way in which the registers are changed vary from card to card. Several "standards" do exist to provide a common interface to drive most video cards (e.g. VESA BIOS and Windows Graphics Device Interface (GDI)), however the current versions do not provide support for switching to an interlaced video mode. As a further complication, some newer video cards cannot be switched into an interlaced video mode - meaning the program described in this paper cannot be used with such cards.

The technique of activating or driving an LCS glasses system also varies from system to system. VGA dongle systems simply require activation - either by modifying some control card registers (3DMAX), modifying video card registers (VRSurfer) or displaying the white line code on the last few visible lines of the display (SimuleyesVR). Serial and Parallel Port systems need to be manually toggled on and off by changing the output of the serial or parallel port in synchronisation with the field rate of the video mode. This must be done by a software routine running on the PC. Ideally the software

[‡] Available from the Intel web site <http://www.intel.com>

routine will not consume very much CPU load so that the computer will also be able to playback the video sequences. The timing of the routine must also be fairly accurate so that the glasses are correctly switched in synchronisation with the field rate of the monitor.

The Stereoscopic Display Interface (SSDI) being developed by VREX is intended to solve both of the above requirements by providing a standard architecture and API (Application Programming Interface) for driving any stereoscopic display system⁴. Unfortunately, version 2.00 of SSDI (the version which was available to the authors) does not currently meet this goal. Although SSDI has very comprehensive support for switching video cards into an interlaced video mode, it currently only provides drivers for a few stereoscopic display systems. Furthermore, SSDI cannot be obtained easily by the public currently - it can only be obtained commercially by purchasing the VRSurfer Webpack. Although it is understood VREX plans to make SSDI more publicly available and release SSDI drivers for a wider range of LCS glasses systems, it is not known when this will occur.

When SSDI is released, it would considerably simplify the issue of interfacing various glasses types and switching into interlaced mode. However, until SSDI is released, any program hoping to work with a wide range of glasses systems must provide that support itself.

Fortunately, Kasan Electronics, StereoGraphics and NuVision do provide software routines (APIs) for driving their LCS glasses systems under Windows. The Kasan and StereoGraphics routines also include drivers to switch some video cards into interlaced mode, however, this support is not quite as comprehensive as SSDI. Unfortunately, 3DTV and Woobo do not provide drivers to support the toggling of their 3DMagic and Cyberboy glasses under Windows. It was therefore necessary for us to provide support for the latter two types of glasses (by writing a software toggler) and provide support to switch the video card to interlaced mode.

The software toggler we wrote uses a separate high priority thread and the *thread sleep* function (part of the Windows 95 API) to achieve the suspend and reactivate operation of the toggler. The toggler we have implemented currently operates with a moderate amount of success. Its operation is occasionally interrupted by glitches when the toggler loses synchronisation with the vertical refresh - this we suspect is due to higher priority tasks (such as interrupt service routines) taking control of the CPU during the vertical refresh period or delaying the reactivation of the toggler thread. Further development will be required to improve the operation of the toggler.

Unfortunately, with regards to interlaced mode it was beyond the scope of this project to develop the necessary routines to switch a large range of video cards into interlaced mode. The only suggestion which we can offer for manually switching a video card into interlaced mode is to try switching the card into 1024x768 resolution - some video cards switch into interlaced mode to support this resolution.

2.4 OTHER ISSUES

The video sequences were digitised and converted to AVI format using a Miro DC30 video capture card and Adobe Premiere software. This combination of hardware and software successfully generated row-interleaved format files from the original video sequences which were in field-sequential 3D PAL format.

The program was written using Microsoft Visual C++ and compiled for operation on the Windows 95 operating system. The Microsoft Media Control Interface (MCI) was used for the playback of the AVI video sequences.

3. THE IMPLEMENTED SYSTEM

Figure 6 shows the user interface of the implemented PC-based stereoscopic video walkthrough. On the left side is the video playback window - in this case showing decision point 1. At the bottom of this window are buttons which appear when a decision point is reached which allow the user to choose to navigate left or right. On the bottom-right of the display are a set of radio buttons which allow the user to select which type of LCS glasses they have connected to the system. The radio buttons have been broken into two groups: those drivers which drive the glasses and also switch the video card into interlaced mode (lower group) and those drivers which only drive the glasses (upper group). If the LCS glasses chosen are in the upper group, it is necessary for the user to manually switch the video card into interlaced mode (see section 2.3). On the upper right hand side of the display are buttons which provide supervisory controls such as restarting the walkthrough, rewinding or fast forwarding the video playback, pausing playback or exiting the walkthrough.



Figure 6: The implemented Stereoscopic Video Walkthrough

4. DISCUSSION

The Stereoscopic Video Walkthrough program works well and certainly demonstrates the feasibility of implementing a video walkthrough entirely on a PC - despite the relatively simple walkthrough implemented for this project. The program currently works well with the VRSurfer, SimuleyesVR, 3DMax and 3Dspex glasses and works semi-satisfactorily with the CyberBoy and 3DMagic glasses. As indicated earlier, the support for interlaced video mode switching currently depends upon the level of support provided by the appropriate glasses software driver. These inadequacies of our current program will hopefully be overcome when the next version of SSDI is released and it is made commercially available.

It is planned that future versions of the program will allow users to construct their own walkthroughs for use with this program simply by providing the appropriate AVI video files and a script defining the sequence in which the files are to be played and the location of decision points. The current version has the names of the video files and the location of decision points hard-coded into the program.

As was mentioned earlier, the program will not work with video cards which cannot be switched into an interlaced mode. In order to support systems with this type of video card, it would be necessary for the program to support the page flipped stereoscopic video mode. This would also require the development of a video playback utility which would selectively decode the odd and even lines of a row-interleaved 3D AVI into separate left and right image buffers in video memory during video playback and in real-time.

5. CONCLUSION

A platform now exists for the easy implementation of stereoscopic video walkthroughs. A PC-based system allows stereoscopic video walkthroughs to be developed and modified without the high cost penalty associated with using video disks. A stereoscopic video walkthrough could be used to familiarise staff with an industrial plant before reaching the scene or allowing a virtual traveller the opportunity to semi-interactively explore a remote place.

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