VIRTUAL STUDIO

A GUIDE TO THE USE OF VIRTUAL STUDIOS

BBC Television Centre Studios
August 1997

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Introduction

At the 1994 International Broadcasting Convention in Amsterdam, the Broadcasting industry was shown for the first time the ability to use a powerful computer to generate a simple studio set in real time. Admittedly the technology was rather crude, the sets were in no way 'photo realistic' and the equipment was prohibitively expensive.

At that time these really were technology demonstrations and although usable, the systems were unreliable, difficult to set up and were really pushing the available technology, but the imagination of many was fired, rumours that this new technology would slash production costs and provide vastly increased utilisation of studios abounded.

Since then there has been a proliferation of companies all vying to sell their solution as best. The camera movement has progressed from just pan, tilts and zooms, to full, almost unlimited camera movements. The set quality has improved dramatically and the costs are descending. There is a bewildering choice of systems, real time, post rendering, pre rendered, 2D and full 3D.

The most important fact surrounding Virtual Sets is that they are not now, and are unlikely ever to be a total replacement for existing studio production techniques. The skills that have been learnt over 60 years of television program production should not be swept away, and in many cases are essential grounding for the newer technologies.

There is no doubt that without a good program idea and script a fantastic set will not make a good program. The technology should never lead the creative input, but when all the elements are right to create something new, absorbing, and hopefully award winning is what spurs most productions, and there is nothing in television more exciting than working on a program that feels right!

There are many ways of achieving the aim of using a Virtual Set to replace a constructed one, and this guide attempts to explain the technology and some of the terminology that surrounds Virtual Sets. It is obviously biased towards the development and uses the BBC has made of Virtual Studios technology and as such all the opinions are those of the BBC, but it is not a sales brochure. The BBC developed systems mentioned in this guide are available from established manufacturers of Broadcast technology, from whom the BBC receives a royalty from each system sold, which is used to support further research into Virtual Studios. We are committed to developing and exploiting this exciting technology by providing technical solutions we feel there is a need for, and a market gap, and providing our production experience to Virtual Set manufacturers to improve their products.

BBC Virtual Studio
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A Brief History

Since the introduction of colour television in the late ‘60s, the techniques for giving the illusion that an actor or presenter is in a different location from a studio have been developed to high degree of sophistication. Variations on this technology are used in almost every weather bulletin throughout the world to provide pictures behind the weather forecaster. All of these systems require a plain area of coloured backing that the forecaster stands in front of (called the foreground). The plain colour is replaced electronically by a different picture(called the background). This background picture can be any video source, still or moving. The main limitation of this technology, called Chroma Key, is that the camera pointing at the presenter cannot move.

If the camera does move then the presenter appears to float over the background picture.

It was not until the mid ‘70s that an attempt was made to allow the actor to move. A device called Scene-Sync was developed to link a camera pan and tilt head to a motorised easel, which then moved the background picture in sympathy with the foreground actor. Scene-Sync was successfully used on many BBC award winning shows such as *Jane* and *Gulliver's Travels*. Despite its success it also had many drawbacks. It was slow to use, difficult to set up and because it drove an easel the background was limited to still pictures. A later development provided a linked pan and tilt head, but mainly due to the servo technology, and the size of the cameras, it still did not give total creative freedom. Since then most of the innovative and successful work in marrying foreground with moving backgrounds have been carried out in the area of motion control. Many feature films now have very complicated effects' sequences where the backgrounds perfectly match the foregrounds. These are usually done with models and camera memory heads which allow the motion of one camera to be repeated by another with a motorised head. Although the computer is now playing an increasingly important role in effect production, many of the best effects are still produced using models, which are then computer enhanced, and composited to produce the final result.

Most television programmes do not have the large budgets of feature films and cannot afford these techniques, so it has been left to the producers of commercials to push forward the effects technology. For very short sequences, and with the budgets available then feature film techniques can be used. To generate realistic looking backgrounds and animation’s a computer cannot produce a whole frame in 'real time' (in Europe, PAL, 'real time’ is 50 pictures per second), but often takes several minutes, so the finished images are stored to disk and then composited with the foreground a field or frame at a time at a time.

This whole process takes many hours - and often involves much trial and error and tests to get the right look. Most of the computer software and motion control systems do not use quite the same language of perspective or position information, so invariably custom software has to be written. It is because of the particular fields of expertise necessary that effects facilities have grown up, and probably the most famous of these is Industrial Light and Magic. Everything must be prepared prior to the studio shoot and very little can be changed once the material has been shot, especially the lighting.

One major drawback to this system is that neither the director, nor any of the craft team, can see the finished effect in the studio and therefore cannot be sure until after the post production stage that the right foreground shots have been recorded. Because of this every shot is always carefully storyboarded.

Unfortunately when it comes to most television production, there is neither the budget nor the time to go through the post production process. Live television output is still the cheapest, and using a multicamera studio provides the most flexible, controllable environment. But in order to reduce the costs of television production the time taken to produce the finished program must be reduced, or other fixed costs removed. Production styles often dictate much of the fixed cost base, and these vary from country to country.

For instance in the UK a newscaster is always seated behind a desk, where in Germany it is accepted that the newscaster may be standing. This instantly places a different constraint on the set design, and limits what the studio set will look like. With a desk there is no opportunity for the newscaster to move, so the cameras used could be robotic. With a standing presenter it is likely that they will move, allowing much more flexible shooting, but at the expense of needing camera operators. All the other production costs are rising, so the option of not building a real set, and being able to change the set, almost instantaneously, offered the potential for real cost savings.

The realisation that by using conventional Chroma Key but with a computer generated synchronous moving background linked to the foreground was first worked on in Europe, strangely enough two companies VAP and IMP were both looking at similar solutions, but using different sensor systems. It was the arrival of the Silicon Graphics Onyx computer with Reality Engine 2 Graphics that allowed the work to succeed, and IMP showed their system at IBC in 1994, this system was to become VAPOUR now sold by Discrete Logic.

The basic premise is that a camera has sensors attached to it so that the pan, tilt and zoom functions can be measured accurately. Once the position of the camera is also measured then the cameras view can be reproduced by a computer displaying what the camera would see, but from a computer model. The initial models were rather simple, but the effect looked great. VAP joined as part of an EEC funded project called MONA LISA, along with a number of other European companies, universities, and the BBC, and in 1994 the ELSET system and the MONA LISA system were shown. Some of the technologies from the MONA LISA project have now been used elsewhere (it was the first ever pattern recognition system shown) and the ELSET system is now sold by ACCOM. Another European system, BEST from Brainstorm was being used by Antenna 3 in Spain.

Chroma Key had also undergone a number of significant developments over the years as well, Ultimatte has grown from a very difficult to operate device, but almost industry standard, into a one step set-up operation, with the Ultimatte 8 being capable of remote control linked to the pan and tilt head computer, making adjustments during the camera moves. Many digital mixers also now boast very comprehensive Chroma Keyers, while the change from analogue to SDV studios has made component recording and operation very cost effective. The development of cold light fittings has also enabled large areas of Key colour to be very evenly lit, further improving the opportunity to extract those important shadows that fix artists to the floor

In 1995 a new tracking system appeared. Until now the only way of accurately measuring the cameras position in the studio was with mechanical sensors on each axis of movement, a tape measure, and a fair degree of patience to complete the initial line up process. As all systems have a slight degree of mechanical slip they needed to be reset occasionally. ORAD took pattern recognition to a new level of achievement, and with a dedicated hardware processor they are able to work out the cameras exact position from a special pattern made up of 2 Chroma Key colours.

One of the major advantages with this system is that no special camera mountings are needed, no track needs to be laid, so the studio process is much faster. ORAD also launched their own Virtual Set system called Cyberset. Another company RT-SET also from Israel, using experience gained in designing flight simulators, launched Larus.

The arrival in 1996 of the new graphics engine Infinite Reality from Silicon Graphics have allowed more complex sets and more freedom of camera movement, as well as providing enough processor power and texture memory to be able to defocus in real time.

1996 also saw the launch of the BBC designed Virtual Scenario, sold by Radamec Broadcast, this system uses a standard 625 line video image as the background, which is moved in sympathy to the foreground by a custom designed image manipulator (also a spin off development from MONA LISA). Around the same time Pseudio from Japan also showed a 2D system, and ORAD launched a stand alone version of their pattern recognition system that could be used with other peoples systems. One of the first was For-A who showed a 2D system based on their DVE.

The Eurovision song contest used a very dramatic Virtual Set for the scoring sequence, at last showing that election coverage is not the only use for Virtual Sets, but most demonstrations still show a large proportion of news and magazine shows.

IBC in 1996 showed all the Virtual Set vendors providing better user interfaces, and starting to realise the overall system design is important. New features added better animation and Virtual Characters, as well as displaying what many Broadcasters have done with Virtual Sets over the last year. RT-SET showed a system for displaying where the artist should move to next in the Chroma Key space.

NAB in 1997 showed that there may be some opposition coming to the stronghold SGI have in the field of graphic computers. Evans and Sutherland launched their MINDSET system, and ACCOM showed their Windows NT system. Lower cost previews were also being shown working on SGI O2 computers. Radamec launched D-FOCUS, a hardware solution designed by the BBC to work with the Virtual Scenario 2D system, or with any other Virtual Set. Depth of Field is one of the most important tools in television to allow the artist to stand out from the background and provide depth to a scene. RT-SET showed a different system for using a handheld camera, that also uses a pattern in the Chroma Key space, but this time projected.

And what of IBC 1997.

From the BBC's point of view this will be a vital show for our development work towards really practical Virtual Studios. As this guide will discuss later there are a number of fundamental developments that we as a broadcaster require in order to make Virtual production as easy as Real Set production. Some of these are undoubtedly a few years away, but some of them are launched at IBC 1997, and are expected to enter production in 1998. Although covered in detail later the BBC is launching ***free-d***, the first tracking system not to use any pattern in the Chroma Key area, and TRUEMATTE a new Chroma Key cyclorama that does not need conventional lighting, and completely eliminates problems of colour spill.

Other developments to look out for are the new SGI onyx2 computer that promises faster performance at a lower price than the previous generation, developments on the NT systems, and

especially in providing higher quality backgrounds that are rendered in non real time, but synchronised to stored real time camera moves.

It seems that we may of come full circle, but the need is still there for cost effective real time studio solutions. For a technology that is only 4 years old, there are a lot of sceptics who say it is too limiting, too expensive or ‘I’ve used Chroma Key 20 years ago and it didn’t work’, but techniques do change, new technologies are accepted, Virtual Studios are not the solution to television production, more another weapon in the armoury, to be used when the program style dictates, after all, who buys tube cameras today?

A BASIC VIRTUAL STUDIO

A virtual studio basically consists of a controlled stage area covered with a chroma key colour cyclorama or plaster coved wall, a suitable lighting rig and the necessary vision technical equipment for combining the chroma keyed foreground action with a moving background. The background view is derived to match that of a real camera in the studio area. The background may be totally computer generated in 'real time', pre-rendered or video. It does not require the use of headsets, which is generally called 'Immersive Virtual Reality'.

Any existing studio or stage can be used, but it will generally be easier to use a fully equipped facility than to set one up on a programme by programme basis unless the run of recordings is fairly long. No matter which system you intend to use, 2D or 3D, there are certain basic requirements that must be met, most of which are covered in detail in the following pages, but read on for a brief summary.

Studio Size

Any virtual set requires a studio space equipped with an area of chroma key of suitable size and colour to accommodate the action the director requires. Studio size has to be 1:1 for the perspectives to be correct, If an actor has to walk 20 feet towards camera, then he really has to do that walk. That demands a studio space slightly larger than the longest move required with the ability to get the camera into the correct position. A good guide is to add 2 metres in all directions over the minimum action area required.

Because the eye and brain are very good at detecting when something is wrong with a picture, even if it cannot say exactly what is wrong, it is always better to allow a bit more room for lighting as well.

That said it is fairly easy to provide masking that allows a Virtual Set to appear much larger than the available space, but remember the laws of physics do not change, and a key light 30cm above a head, does not behave in the same way as one 3m above.

Chroma Key

In order to 'cut' out an actor from a background, there are only two methods currently available, chroma key (also called blue screen or Travelling Matte) and Rotoscoping (drawing round the foreground action frame by frame).

Live working demands the use of chroma key, where a plain, evenly lit colour is used to derive an electronic signal that shows where the change from plain colour to foreground action is for each television line. This signal can then be used to add the foreground to a different background. Real shadows from the foreground action can be picked out using a brightness signal and used to darken the appropriate areas of the background.

Cameras

As yet none of the virtual set technology is aimed at film cameras, although some of the sensor technology is bound to, and by virtue of using film the result cannot be seen until post production. All virtual studios need to use CCD video cameras, the latest also offer 16:9 working as well. Full control of contours or aperture correction is essential as this can lead to black edges around the

foreground action, especially when working with green chroma key. An operational control panel or master control panel that gives numeric readout of the cameras parameters is also very useful.

The feed from the camera to the chroma keyer needs to be digital or ideally full bandwidth triax or multicore component.

Sound

All ‘real time’ virtual set systems have a delay between the action occurring on the studio floor and the composite picture appearing on the video monitors. Currently this ranges between two and six frames. It is important that users of the virtual studio are aware of the video delay to ensure that suitable sound delays can also be added to correct the lip sync on the programme output. This is especially noticeable if the programme includes a two way interview, or the presenters ear piece is fed from open talkback where they can here their own voice coming back, bit delayed.

Live audiences cause additional problems as the audio delay needs to also be inserted on their clean feed. Delay must not be used in the foldback to the audience, or they will hear a distracting echo.

Infrastructure

The basic vision system should ideally be digital, but as a minimum must be component until after the composition of foreground and background. Whether a stand alone chroma keyer or a studio vision mixer is used it is ideal for each camera to see their own composite at all times. This is fairly easily arranged in 2D systems, but in a 3D system there is often a limitation on the number of background computers. One being the minimum allows a cuts only scenario, with no preview of the next shot. With 2 computers then mixes can be performed, but a fairly complex arrangement of switching position sensors to the correct computer is needed. The cost and complexity of a multicamera 3D shoot can be very high.

As the cost of computers fall then a lower cost, lower resolution background can be provided for previews, with the super computers providing only the main vision feeds.

Virtual Studio Systems

There are now 3 different basic methods of achieving a Virtual Studio.

In order for the virtual set illusion to work, any camera movement that affects the foreground action must also affect the background image. In all cases some form of sensor or robotic camera mounting has to be employed.

Pre rendered graphics

The first system utilises pre rendered backgrounds that are stored to a video disk. These are then replayed to match a robotic camera move. The BBC has been using a system like this for 4 years for the main news bulletins.

The major benefit of this system is the low cost, and providing the foreground camera is in the correct place then the illusion can be very good. The background image can be photo realistic as it does not have to be rendered in real time.

The disadvantage is that the shots always have to be the same. Although new moves can be generated this usually take too long except in the initial set-up period, and the camera operators cannot make any slight adjustments on shot.

2D

In television production, many of the shots do not actually move at all, and when they do it is only a small pan or zoom to accommodate the artists movements. In fact some of the research at the BBC showed that as much as 90% of moving shots were only pan tilt or zoom.

In these cases it is not necessary to have a super computer rendering the full view of a set all the time, because unless the camera mount is moved (dolly, crab, track or height) then the viewpoint looking at the background does not change, and hence neither does the perspective.

In these cases the background can be moved in sympathy with the foreground by using a DVE, or looking at a window on a larger rendered area on a lower cost computer. The background is not generated in real time, hence the computing power required is much less. Using multiple layers allows for garbage mattes, or foreground objects.

Virtual Scenario

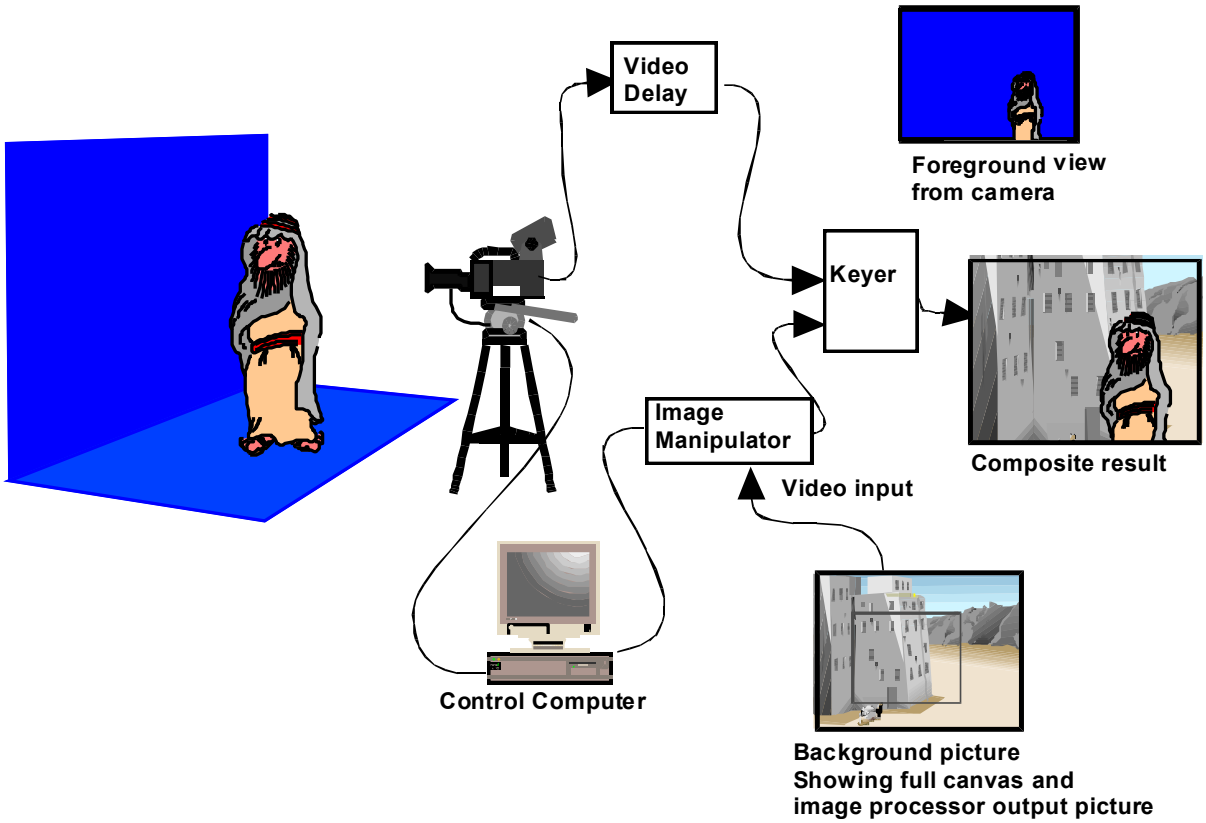
In 1995 the BBC realised that a DVE could be used to provide the necessary movement for a Virtual background, but that the cost and quality of multi purpose DVE's were not suitable. The solution was to design a custom image manipulator that has superb quality on horizontal, vertical and zoom moves. The 2D background is a standard 625 line digital image which is then enlarged to give a canvas to pan over.

The image manipulator takes in a serial component digital picture and can provide up to eight times zoom, without the pixelation artefacts of most other DVE's. In fact the image tends to soften as the zoom is increased, much like a background would when a camera zooms in to a foreground actor.

This image can be created in many ways including a computer model, live video or stills. The planning of the shots needs to be accurate, as the backgrounds are all previously recorded material, but the quality of the sets is not limited by the speed of a computer.

The image manipulator is linked to the camera pan and tilt head, as well as the zoom & focus of the lens. A simple control allows the image manipulator to be set to 1:1 size and engaged or disengaged to the camera head by the camera operator who can set up the shot with the actor and then set up the background to match the actor. When engaged, the background follows the camera movements, providing the realism of a virtual set.

Several image manipulators may be combined to offer moving foreground mattes, garbage matting, or even many layers of image. It is possible to use the 2D system to provide some perspective by 'layering' images, rather like the Disney cartoons, using differential movement on the layers. Live video can be inserted into the image and panned around with the image giving the effect of a video wall.



A Block Diagram of the BBC 2D Virtual Studio System.

Here the main components of the 2D system are shown. The cameras pan, tilt and zoom information is fed to the control computer which controls the image manipulator to show a portion of the background image that corresponds with the movement from the camera.

There is a delay of four fields through the whole system, so the audio needs to have a compensating delay added to it.

The BBC 2D system is available from Radamec Broadcast.

3D

Three dimensional Virtual Sets, were the first to be developed, they all use a supercomputer to generate a view of a computer model as though it had been constructed in reality. The foreground

cameras position and view control a virtual camera in the computer that produces the background view. Any change in the camera position or view produces the correct and corresponding perspective changes in the virtual set.

For full 3D, to work correctly the system uses a camera with sensors fitted to all of its axes of movement. It also needs to know precisely where the each camera in use is within the studio. The virtual camera has to be able to reproduce the lens distortions and nodal lens shifts as well so that the Virtual image and the real image align exactly. The output is then combined in a keyer with the foreground to produce the composite picture.

As it is essential that the perspectives match, the setting up procedure and accuracy demanded is much greater than for the 2D system, and depending on the type of sensors used can take a long time to get correct.

A Silicon Graphics IR Onyx computer is generally used to generate the background image and an appropriate alpha or mask image. These images are changed to reflect the camera movement. Whilst the Onyx is extremely fast, it is still unable to generate a 'photo realistic' set in real time, so depends upon using textures to make the set look more realistic. Other graphics engines are now becoming available, but none are as powerful as the Onyx, and hence cannot generate as complex a set. This may not matter for some productions, so an Onyx may not be essential.

As a very expensive computer is required to generate the background image, working in a multi-camera studio is either very expensive, or rather complex. If a full foreground and background composite is not required all the time for each camera then less computers can be used, but there is the additional complexity of switching the tracking information to the computer the correct time ahead of cutting to that output.

The 3D system can also be used for animation. This means that a weather man standing next to a spinning globe showing the weather patterns across the world is now possible. A set can build up around the actors or change from one shape to another.

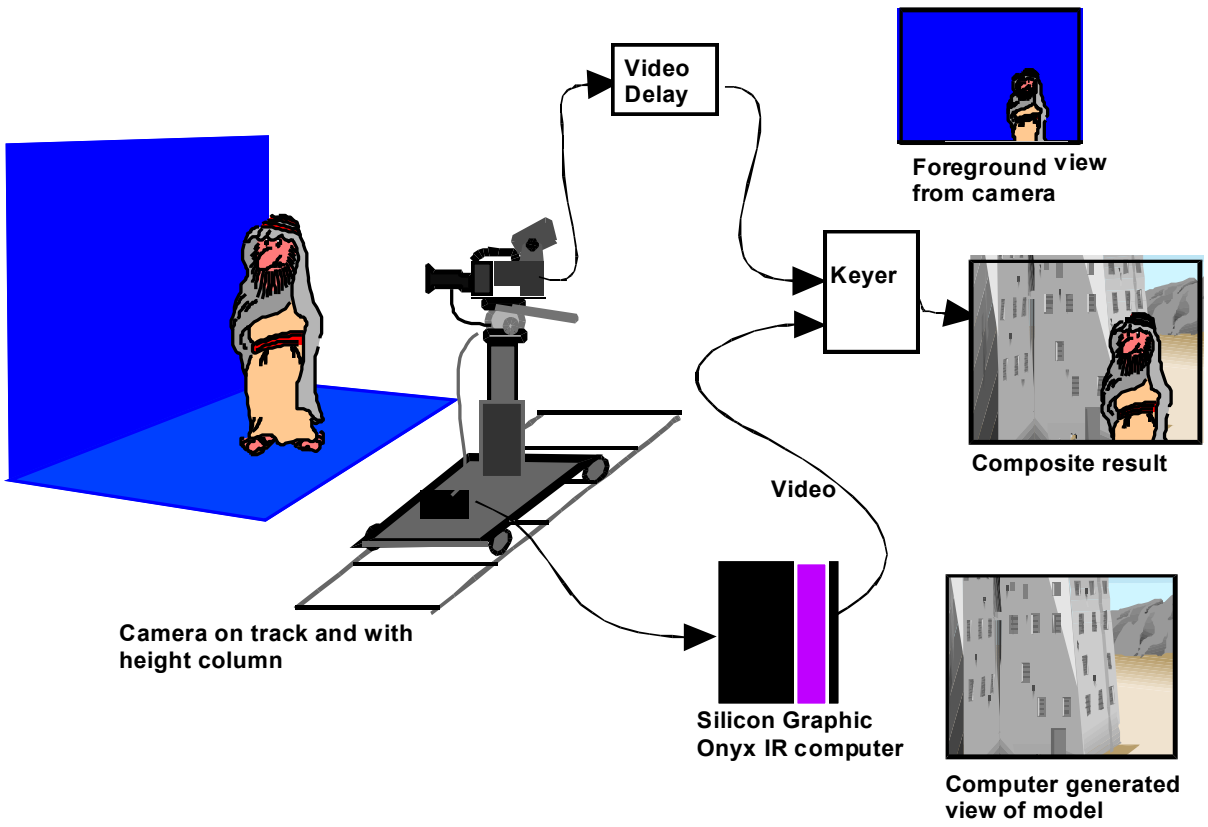
Limited only by how many polygons the computer can generate in 1/50th of a second, effects that were impossible to generate in the studio now become a reality.

There are a number of software and solution providers who are offering packages that make the creation of sets, animation, audio stings and videos link seamlessly into the computer.

As with a real set, the one thing they all limit is the total creative choice of on the spur of the moment decisions.

All the features and attributes to create a set are entered on to the computer and, rather like a word processor, allow some changes immediately but cannot totally change the text without work from the operators.

There is a lot of change in these areas and the tools provided will enable the producers to have a greater freedom if they get involved in the process. As with any emerging technology, the consumer has a large input into the way developments occur and progress.



Simple Diagram of the Main Components for a 3D System

The camera on a tracked dolly with height column in this case, uses additional sensors to determine its location in the studio. The position and orientation of the track has been carefully measured, so the computer knows where the camera is in relation to the action. The position and zoom and focus information is combined to provide a virtual camera view of the 3D model in the computer. This is then output as video to a conventional keyer to be combined with the foreground.
A matte or alpha channel is also available, which is often used to extend electronically the blue screen area.

The future

As the cost of the full 3D system is very high, and it is only required for a limited number of shots it should be possible to combine the benefits of the 2D systems with the 3D.

By using the 3D camera tracking to ‘load’ backgrounds into 2D systems a sort of hybrid could be created that allows a number of cameras to be fed from the same supercomputer, but not provide full 3D movement all the time on all the cameras.

The price of systems will fall, and there will be a fair degree of price to performance choice for the customer. The top end systems will always be expensive, but then so is a television program.

The Basics Requirements for a Virtual Studio Shoot

Concept

Virtual studios are not just about recreating an uncomplicated four wall set nor election coverage, with flying graphics and walk on maps. For a scriptwriter to be told there is almost no limit to their imagination is very stimulating. The idea for the use of any virtual studio needs to come from the concept of the production, and the script. Replacing a conventional set with a 'Virtual Copy' will not only look disappointing, but will not help the use of Virtual techniques for the future. Of course it is possible for Virtual Sets to save money, there is no storage cost, setting or striking, and the turnaround to another program can be almost instantaneous, but the major benefit is in making the impossible real.

Planning

Due to the complexity of computer generated sets they cannot simply be changed within the shooting environment. The scenes must be story boarded before the studio day and each shot well documented for camera position and artist moves. The planning process has to include the look and feel of the sets, which Is finalised at a much earlier stage than with a real set.

The use of a planning software that can be used to view 3D models and print out camera positions and floor plans is invaluable. One package, Virtual Production Planner from Colt VR was developed with BBC Television Training department. It is a replacement for the traditional cardboard model, that runs an a standard PC and that allows things like camera shoot off and viewing angles to be easily checked. Although the software does not yet import models from SGI machines this will be available in the next release

Design

The design of a virtual set will need the same time, skills and effort as needed for a conventionally designed and constructed set, but has the advantage of allowing far greater freedom.

The designers who create these computer images have a range of specialist skills which combine studio planning expertise with a knowledge of computer modelling and image generation techniques. The art of designing sets to give the depth that television requires is vitally important with computer generated sets, that tend to have a cleaner appearance than real sets. The designer now has the ability to colour and light his creation, bearing In mind the artists will also have to be lit.

It is important to have a television output from the computer as the VDU often looks far brighter than the final image will be, and once a model is lit and textured it is not easy to change.

Golden Rules

- Storyboard each shot
- Include in the planning the extra shot you may not need, but would like to try
- Design each scene to include more than it is planned to show
- Make sure everyone involved on the studio understands how to treat a chroma key area
- Avoid artists wearing anything in the chosen keying colour. Try and avoid any chrome or reflective finishes (like PVC).
- Have a detailed plan with artist , camera positions and lens angles marked for each scene.
- Check the artist's movements against the story board and place markers or masking as required.
- Try and use some 'real' props to assist the artists in relating to the environment.
- Walk through the action with the craft team & actors. Note any specific details that must work.
- Use stand-ins on the stage for the lighting and keying to be set.
- Return to a lit perfectly keyed set-up.

Rehearse and record that set-up. It may be that other set-ups are very similar: if so it will save a lot of time if these are recorded together, rather than in story order.

Limitations

Of course with any technology there are limitations, and with a new one there are bound to be more than some producers will accept. As time and user knowledge increases many of these will be solved and others will appear, as users push the systems to their limit.

Lack of planning

Although this may not sound like a limitation, until the production team are masters of Virtual Sets the phrase 'can we just try this' send shivers down the craft staff. Most of the time the answer is yes but it may take a while, and you invariably find yourselves resetting to an earlier set-up.

Virtual Sets need careful planning to work out what you will see, how it will be shot, how to light it, in fact all the things you would do if you had a real set.

Fail to do this at your peril, or at least your budget.

Graphics Engines.

The heart of any 3D system is the rendering engine that actually draws the background pictures. It is obvious that this is where there are improvements needed, but also at a lower cost.

Of course the user requires real time defocusing, motion blur, lighting and unlimited polygons, as well as full depth channel and alpha channels, but he is probably not prepared to pay for it, even if it were technically feasible. The total television market is small compared to simulation providers so our needs will undoubtedly not appear until others are asking for the same thing. Competition in the

market will help, but we believe it will be another 4-6 years before the rendering engines are really powerful and cost effective enough for most users.

Camera Tracking

Camera tracking is pretty well solved for small studio areas, or for 2D systems, but in a large studio area, or to allow the use more specialised camera mounts is currently impossible. Our hope is that the BBC ***free-d*** system, shown at IBC as a prototype system, will fully meet our specification for a large studio, and so remove this limitation. Other companies are also engaged in work in this field, but to give an idea of some of the current limitations with the current technology here is our specification for a camera tracking system.

1: Must work without targets in the Chroma Key area and allow real sets to be used

2: Must work with all conventional camera mounts so allowing manual operation

3: Must work with all existing cameras without significant modification

4: Must allow 360 degree shooting in an 800sqm television studio (height 0- 20m) with the necessary accuracy for a 3D set system

5: Must work with multiple cameras at once

6: Must allow defocusing

7: Must be reliable, and be frame based

8: Must minimise set up time, and not need recallibrating during the day

9: Should be able to allow handheld cameras

10: Should be cost effective

Depth of Field

As television is essentially a 2D medium then depth is achieved by design, lighting and selective focus. Being able to have the main action in focus and the lesser action or background out of focus is a dramatic tool that forces the viewer to look where the director wants them to look. There are ways to defocus a computer generated picture, but these are either very computationally time consuming, or require pre rendering, and then mixing between the sharp and soft version. It may be that the new hardware D-Focus can be used with a 3D model to allow defocusing, but the current generation of Onyx computer cannot output the depth information at the same time as the main picture.

Other graphic engines that use a full rendering engine to provide the alpha channel could provide the required signal, then D-Focus would provide a solution to this problem without increasing the demand on the computer.

Chroma Key

We have no doubt that eventually a completely new solution will be found to the way of removing unwanted foreground and replacing it with a different image, but until then we have to use colour as the means of separation.

When a coloured cyclorama is used then it must be lit to a certain level, and this light will bounce off the cyclorama causing spill of colour onto the foreground. Techniques for removing this excess coloured light will improve, but will always cause additional problems.

The most satisfactory result is achieved when the colour is all of one shade and luminance, here the use of cold light (fluorescent) has helped, but any imperfections in the paint or cloth used also affect the result.

Shadows, that are essential to place the action on the floor, are reproduced by a variation on the luminance of the blue. If the lighting is uneven then it is very hard to get good shadows.

Depth keying and Artist positioning

In a real set an actor will pass around objects between themselves and the camera. In a virtual set everything except the actor is in the background. Certain items can be made to appear in front of the actor by use of the alpha channel providing a matte for the object and switching the object in front when required.

In fact an actor ought to be able to put their arms around a virtual pillar. This would be depth keying, and it assumes that the keyer is fed with the models depth and the real cameras scene depth. Currently this is provided by a manual switch or by infrared transmitters on the actor. Obviously this not accurate enough and again a new technology is required. We need to know exactly where all the parts of all the foreground action is to enable full depth keying, but also the actors need to know where the Virtual Set is.

There are currently two methods that have been developed, one involves shining a blue light on the floor showing the next position, and the other projecting an image of the set onto the floor, but as we are still forced to use chroma key, these cannot be bright enough, or varied enough to be the perfect solution.

Operational Skills

Perhaps one of the largest areas that is not covered by the software vendors is where do you get skilled people to operate the Virtual Studio. Is it better to take computer people and teach them television or vice versa. In fact it may be we need an amalgam of existing craft skills and computer literacy. The main problem is that the computer operating systems are not like the traditional black box approach. The thought of using a mouse to cut a talk show does not go down well with most productions. This new technology has to work within the traditional studio, and should not increase the head count. As skills develop it will become easier to see where the equipment will fit best and who is best suited to running it.

One thing is certain, you can not ‘turn on and go’

3D Model Creation

The basics

For Virtual Sets the computer model replaces the constructed wood and steel set. The process in building a computer set is similar to a real one. First the design is worked out, then the building commences, finally painting and lighting.

Unfortunately in order to complete all of these stages and provide a high quality set many tricks have to be used because the computer is not always fast enough to draw the model in real time.

Any computer draws its pictures using either pixels or polygons. Most choose to use polygons because it is faster to draw a triangle, than all the individual points that make up a triangle.

Obviously if the triangle needs to be filled in, this takes more time, and if it is shaded, even longer, but sticking a picture onto the triangle takes no longer than filling it in. This is called texture mapping, and is the most common way of providing a very high quality look to a simple model.

Modelling

Camera Tracking

In order to use any virtual set system, the real camera - or rather the picture it produces - has to match the picture provided by the background. To provide the background system with the real cameras position within the studio, its orientation and angle of view is no mean feat of technology, and has probably been one of the most limiting factors in the acceptance of Virtual Studios. Unfortunately until now there has not been a tracking device that allows any camera mount to be used, within any studio size, without imposing limitations on the production.

Mechanical Sensors

The simplest of these are mounted on a pan and tilt head as well as the zoom and focus rings on the lens. The sensors are usually optical encoders to give the required resolution, which may be typically 1/100th degree. The camera is mounted on a tripod so the base cannot be moved. Once set up, the repeatability is very good but the effects achieved will be limited to pan, tilt and zoom. Precise measurements are needed of where the camera is in the studio are required for 3D systems.

To achieve the full 3D movement the camera mounting needs to have additional sensors attached for height, position and orientation. This can be achieved by barcodes on the wall, magnetic stripes on the floor, 'dead reckoning' from a datum point or more commonly mounting the camera on a track. The more axes of movement that are required increases the complexity of the set-up. The initial set up time of any mechanical system is long, and once set, any changes are very time consuming. All the systems suffer from some slippage over the day, so a return to a datum point is required. The camera must also be mounted perpendicular to the floor especially on cranes.

Robotic Pedestals

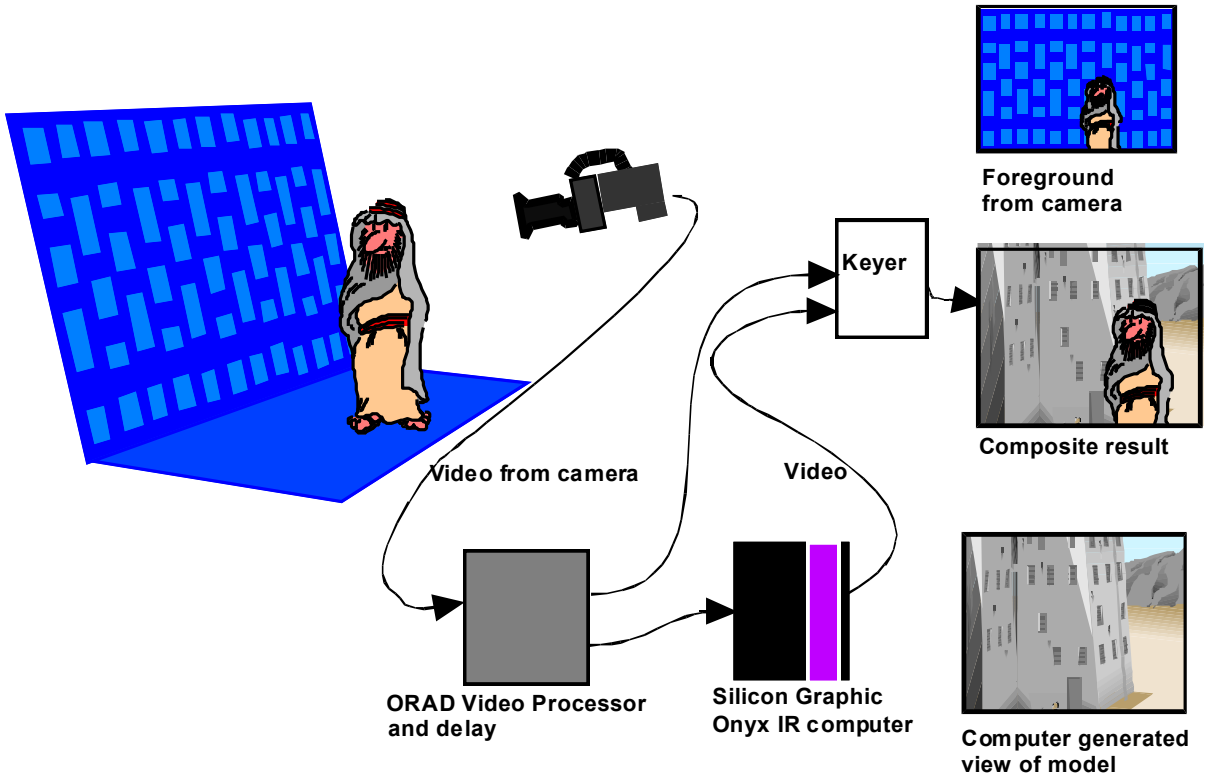
Some systems use the robotic abilities of motorised pedestals, commonly found in news studio’s, to achieve the 3D moves. rather than laying a track. This provides much greater freedom, but generally the pedestals are slow and suffer from orientation changes, as placement of their targets for home information is difficult. Also being robotic, they follow predetermined moves rather than the cameraman reacting to the artists movements. This is very limiting if the artist does not get to the correct marks in the set.

Motion Control

Motion control rigs offer the ultimate in sensor mounted camera mounts as they are all designed for repeatable moves, but cannot so easily be used for manual operation. They can perform moves very quickly but then tend to be large and noisy. Few of the rigs can be moved, which limits which studios that can be used. The benefit of this type of system is that the camera information is recorded in a form that can be used in the post production rendering process to give higher quality images than can be produced in real time.

Pattern Recognition

One of the most advanced technologies, introduced by ORAD around two years ago, uses a custom designed, and patented pattern, set within the chroma key area. This consists of a mathematically designed pattern from two shades of blue, that can be scaled to almost any size. The foreground camera picture is sent to a special image processor which then analyses the picture to it to compare it with the pattern it stores internally. When a match is found it can then work out what translations have occurred to the pattern, and from this where the camera must be to produce the picture.



Simplified diagram of ORAD pattern recognition system

If the pattern is mounted vertically then in order to differentiate between track and zoom an additional zoom sensor on the camera is required. This technique was the first to allow the use of a handheld camera, but in order to work correctly some of the pattern must always be in the cameras view and in focus. This places limits on the size of studio the system can be used in, and also places additional constraints on the chroma keying.

Future enhancements promise the ability to use multiple patterns, therefore not limiting the direction of shooting.

Optical Marker Tracking.

Shown for the first time at IBC 1997 is the new BBC tracking system called ***'free-d'***

This is designed to give the freedom back to the camera operator and director by removing many of the existing restraints to camera tracking.

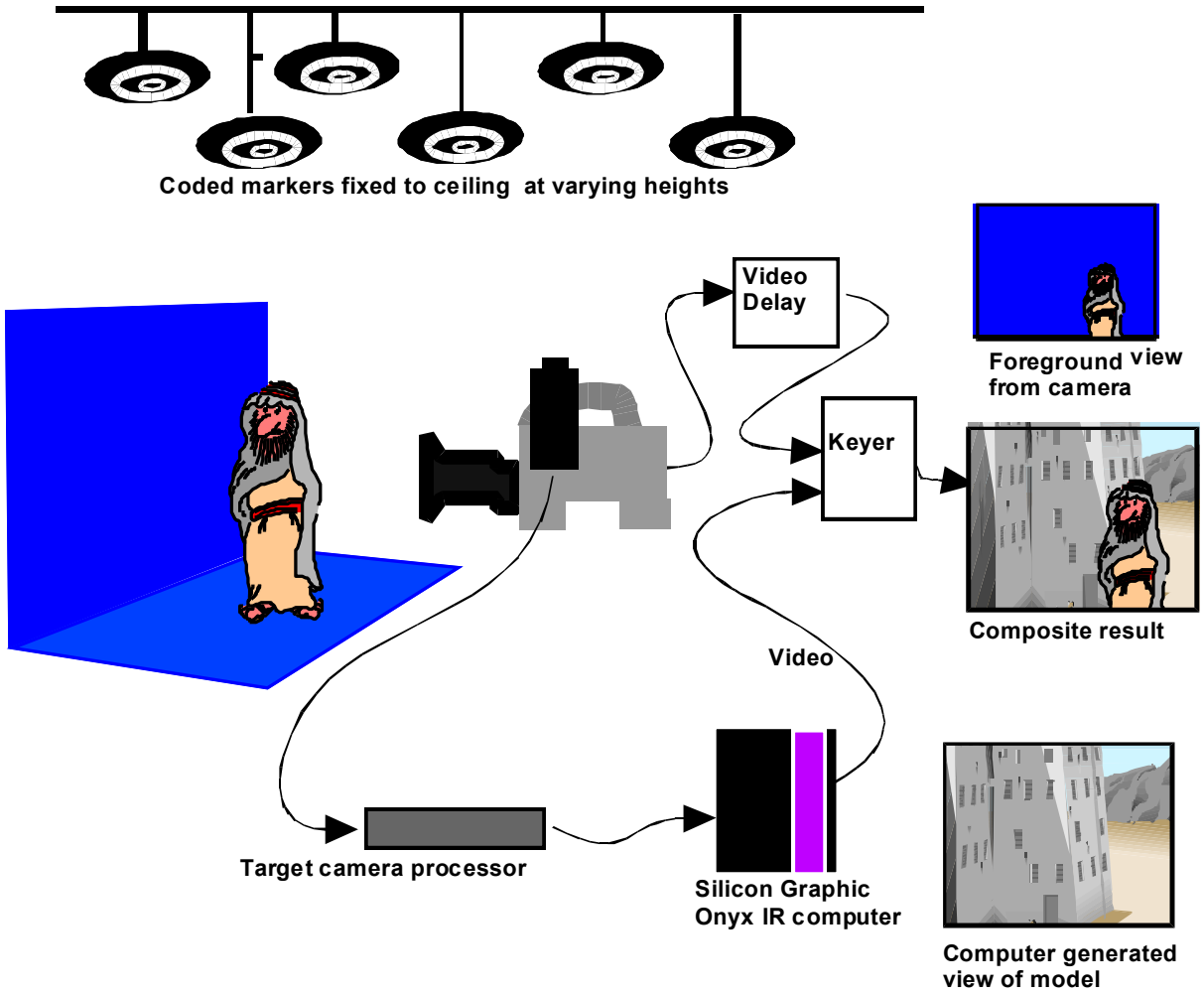


Diagram of ***free-d*** tracking system

The system consists of a number of small markers approximately 20 cm in diameter, installed across a studio grid, between the lights at varying heights. As this installation is permanent the measurement and set up procedure is only carried out once. The camera viewing the foreground is fitted with a zoom and focus sensor, and an additional camera attached at 90 degrees facing the markers.

The camera is fed back to a small 1U hardware processor that then outputs the foreground cameras 3D position and orientation. Because the system is camera mounted any existing camera mountings can be used, as long as the tracking system can 'see' 3 ceiling targets.

The system allows for any number of cameras sharing the same targets, hand held cameras, 360 degree pans, and can also be used to allow virtual characters and objects to interact with the real set as the system does not need any information through the lens of the foreground camera.

Chroma Key

The technique of Chroma Key has been refined over many years since the introduction of colour television, and is a technology most people think they understand. But it is one thing to get a good result on a small area such as a weather backing, but quite another over a large 100sqm cyclorama and floor. Good results are largely an iterative process involving set designer, lighting director, camera control, and keying operator.

The first choice to be made is that of the colour of backing material, and type of keying area. Any primary or secondary colour can be used to key from, but not all keyers will accept all the colours. Blue is the normal choice as it is furthest from European flesh tones, but if the artists are black or going to be wearing predominantly black clothing, green is a better choice, or a higher luminance blue. If the chroma key area is fairly small there is less spill of colour from using fabric as a backing than paint, choice of keying colour also needs to be chosen such that it is not in the foreground as well, particular attention needs to be paid to artist's eyes and costumes.

From the story board and floor plane the area of colour required can be worked out. This is best if all the shots can be achieved on a single drop of coloured cloth laid from ceiling down to floor and then forwards to the camera position, or the back of linoleum painted, rather than have to include sides or corners. There is also a propriety plastic material available, although this picks up footprints rather easily. Perspex can be laid over the key colour to give reflections of the artists.

Where possible always allow at least 2M additional space around the action before any vertical cycloramas. The exception to this is panels used to provide doorways.

Provide cloth overshoes for everyone working in the Chroma Key area, and mats out of vision to wipe feet on. This is essential if delicate shadows are being used.

The setting up of the keying will always be a compromise on a moving shot, unless the keyer allows dynamic control of its parameters, and even if it does there is rarely enough time to get perfect results. Using the auto set-up on the keyer will nearly always get a good result, that can be used as a good starting point for the lighting and set designer to work from.

Use the matte or Show Key options to get a black and white image of how well the keyer is working.

Some keyers can use a frame stores to 'grab' the clean blue area and then provide a difference signal to help eliminate unwanted defects, these are of little use with virtual sets as they were designed for static or motion controlled shoots. It is important to recognise problems caused by camera defects, now that CCD cameras are very common misregistration is very rare, the most noticeable is aperture correction, that can cause black lines around the foreground objects. This is most apparent with green chroma key. Another problem is the colour shift given to out of focus objects.

Design can also help by ensuring the artist are not wearing shiny items like pvc or belt buckles and worn glasses ideally need to be flat glass. Avoiding empty glasses as props, chrome items, or large props that will create shadows under them.

Many of the constraints of using a coloured cyclorama can be overcome by using by using a technique called Front Axial Projection . This was first used for blue screen on the film Tora Tora to

shoot model submarines. The basis is to use a flat screen covered with semi silvered circular balls, the same material as is used on reflective road signs and safety jackets. Each ball will reflect light back along the path it enters the ball, there fore if a blue light is shone through the camera lens it is reflected back to the camera, likewise if a picture is projected then the screen can replace a back projection screen, with the benefit that if light falls on it then the projected image is not desaturated.

Front axial Projection is very useful for chroma key work, because the screen only appears blue to the camera, objects in front of the screen do not get blue spill.

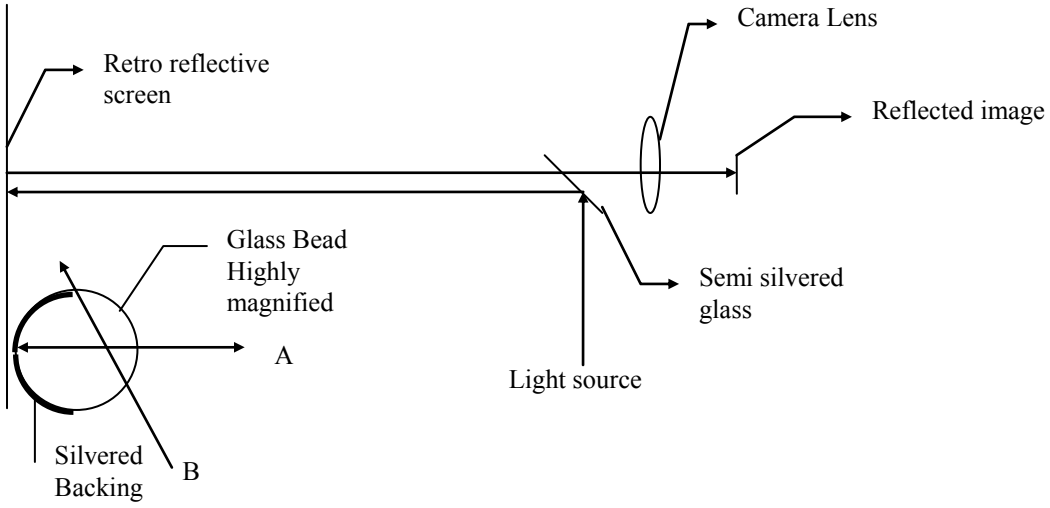


Diagram of front axial projection system

But there is a major problem with the screen material. It only works over a limited acceptance angle. If the light source and camera are at right angles to the screen, and therefore the glass beads then the light is reflected back to the camera. If the camera and light source are at an angle to the screen then the light is not reflected back to the camera, and the screen will look grey. This means the material cannot be used for a backdrop and a floor, because the acceptance angle is too great.

What is required is a material based on this principle, but that will work on the floor as well as the backing, and this is being shown for the first time at IBC 1997. Called **Truematte** this new material developed by the BBC will work over a very large acceptance angle, but with slightly less gain than traditional material. It has a dark grey finish such that lighting will not desaturate the reflected light, but still allow shadows. The material is still being tested but shows much promise as a replacement for the conventional cloth or paint. One benefit is the illumination, although ideally it should come through the lens, can be achieved with a ring of LED's around the lens. About 20 watts to light a 36 sq m cyclorama.

Chroma key is a well established technique but above all else to achieve realistic results takes time and experience.

Lighting

When lighting for a Virtual Set the lighting designer has to satisfy the basic chroma key requirements as well as the blending of foreground and background. This limits some of the lighting effects the designer may wish to use, such as strong shadows, high contrast or very low light levels. The virtual set design must take into account the finished combined model and studio foreground lighting. There is no point in providing the Virtual Set with long dark shadows if the actor cannot cast the same length and direction of shadow in the studio(vampires excepted). This means the studio must be large enough to get the light source into the same direction as that in the computer model.

Lighting provides the necessary realism on to the foreground actor and stops the cartoon cut-out appearance that is a feature of many chroma key shots, no matter how good the keying used is. The model must be lit in such a way that the studio lighting can be made to match and be sympathetic with the overall feel of the production, especially if not all the scenes are virtual. Here the lighting designer needs to work closely with the set designer and modeller to achieve the desired results. A larger and fully equipped studio also makes the final lighting task easier and quicker than a small or bare stage.
Using Chroma Key provides a huge limitation on the actual design of the set because of the demands placed on the lighting director to illuminate the Chroma Key area. Backlit cycloramas can help but it is very hard and expensive to design a backlit floor. The other problem with baclklit cycloramas is the amount of spill generated. It is usual to try and keep a minimum of 2m separation between the artist and cyclorama, but this needs to be at least doubled with a backlit cyclorama.

How the actual lighting process is achieved is down to the individual lighting designer, but as a guide it is better to start by lighting the action correctly, and then light the chroma key area. This will also involve moving the action lights as well. Remember shadows cannot be lit out, and the chroma keyers rarely provide enough control over the shadow generation as they should.

Lighting the backdrop with fluorescent light will help to keep the studio cooler, as well as provide a very efficient and even illumination, but not very controllable.

With the new Truematte material all this has changed. The illumination for the cyclorama is now fitted to the camera, and this means the camera needs to be about 2M away from the artists. The lighting director is now free to light the action, and need not worry too much about the chroma key element of the composition. The shadows are now more controllable by lighting alone.
In tests we have been using very large light sources, 20Kw to provide a key across a whole stage, as this guarantees the shadow will be correct, and also provides very even illumination. Another option is to use a follow spot.
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Glossary of terms

Alpha Channel	This is another name for a key channel. It is used to allow objects in the background scene to appear in front of the foreground.
Aperture Correction (Contours)	A special signal applied to cameras to make the picture 'look' sharper but this can cause black lines around foreground objects
Axes	Term for directions of information. X is along, Y up and down and Z is depth.
Background	Term given to an image that is used as the primary source for a combined picture.
Blue Screen	A film technique that uses a plain coloured area, in front of which an object or actor is placed. Through a series of processes the coloured area is removed and replaced with a different image. The screen colour does not have to be blue.
Chroma Key	Television name for Blue Screen.
Colour Suppression	Technique for assisting in the removal of the screen colour, that reduces the problems of screen colour leaking around the edge of the foreground object. See Fringing.
Composite	A picture made up from a background and one or more foregrounds.
CSO	Colour Separation Overlay. Original BBC term for chroma key.
Foreground	Term given to a picture placed over a background.
Fringing	Coloured light from the chroma key screen bleeding around the edge of the foreground object.
Garbage	Unwanted parts of the foreground that need to be removed. The process for removing them is often called garbage matting.
Garbage Matte	A process used to cut out unwanted parts of an image from a foreground picture.
Keying	A television term used to describe a process for electronically combining pictures together.
Key Signal	A special television picture that carries a black and white representation of the foreground blue screen, where the screen colour is black and the foreground white.
Layering	Alternative term for compositing. It describes how a picture is built up in layers, starting with the background and adding a number of foregrounds.
Matte	An electronic image used for masking. If it is a moving image rather than a still it is called a travelling matte.

Motion Control	A process of motorising a camera mounting and then using a computer to control the move of the camera. Allows shots to be accurately repeated indefinitely and the positional information used later.
Motion Blur	The effect on a viewed TV image when an object is moving very fast.
Polygons	The building bricks of a computer image. These are usually triangles, and the complexity of a computer image is expressed in the number of polygons needed to draw the image on a screen.
Render	A computer term for drawing a picture to a screen.
Real Time	A picture produced in 1/50th of a second or less.
Texture Mapping	The process of placing pre-rendered images onto the polygons in a computer model, rather like wallpapering a room.
Ultimatte	A commercial device for compositing Colour Screen pictures.
3D	Three Dimensional. Having information in X, Y and Z axes.
2D	Two Dimensional. Has information in X and Y axes only. Any apparent depth is an illusion, created by perspective or lighting, such as in a painting.