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System and method for Keystone Correction

FIELD

The present invention relates to a method of and system for correcting keystone distortion in an image.

BACKGROUND

In order to capture an object in 3D for later display it is necessary to take 2D images from a range of locations. For example in order to reconstruct a 3D scene on a multi-view Autostereoscopic 3D display, the original scene is captured using an array of cameras. The array of cameras may be placed along a track, with each camera pointing at the centre of the screen plane. If the scene is static, a single camera may be moved along the track instead of an array of cameras. The necessary light-field is captured to reconstruct a horizontal-parallax-only (HPO) 3D scene.

Similarly, to capture a full-parallax 3D scene (where data exist along both the horizontal and the vertical axes) the horizontal array of cameras described above is now expanded along the vertical axis.

Using commercially available CCDs with fixed lenses, the sequence of images captured by the camera array is inherently plagued with keystone distortion. This is attributed to the fact that the CCD plane is not parallel to the screen plane at various camera positions along the camera track, except when



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the camera is at the exact centre of the track. Keystone distortion would, for example, make a square appear as a trapezoid.

In current systems, keystone distortion may be corrected by applying geometric distortions. The implementation of these methods requires the availability of these geometric functions to the person implementing them.

A programmer wanting to correct the keystone distortion will need to custom build the modules to carry out the transformation. Geometric distortion for Keystone correction is not a standard part of commercial software, and customising such functionality may be time consuming and cumbersome.

Another disadvantage of using geometric distortion is that these functions take time due to the calculations involved. For a single image, the impact may be negligible. However, for a large sequence of images, the time taken may be long.

SUMMARY

In general terms the invention relates to recreating the capture configuration in a virtual environment and taking a virtual image of each image from a location which will correct the distortion. For example if the original image was taken from the left of the centre line, then the virtual capture would take place the same distance from the right of the centre line. The image may then be stretched in the horizontal axis according to how far the camera was from the centre line.

If the camera sequence is replicated in the virtual environment, the image sequence may simply be reversed (by renaming) and the image sequence

recaptured in the virtual environment. This may have the advantage that there may be no computational cost. This may also have the advantage of being faster and more intuitive. The capturing of a reversed image sequence in a replicated 3D environment corrects the keystone distortion inherently without any geometrical transformation.

Customized capture systems with different camera arrangements may similarly be used.

This method may use parameters of the original capture geometry such as

- 1) lens FOV,
- 2) view distance of camera to the screen,
- 3) track length,
- 4) image resolution, and
- 5) size of the image sequence.

A virtual 3D environment replicating the original scene and capture system may be created using the provided original capture geometry parameters. A virtual slate may be created at a position replicating the original screen plane position. A virtual camera replicating the original camera may capture the reversed original image sequence (each image of the sequence pasted onto the slate-screen one at a time) and may naturally correct the keystone distortion that exists in the original images.

In a first particular expression of the invention there is provided a method according to claim 1.

In a second particular expression of the invention there is provided a system according to claim 18.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more example embodiments of the invention will now be described, with reference to the following figures, in which:

Fig.1 – is a Flow Chart according to an exemplary embodiment.

Fig.2a – Shows a HPO capture system with the Screen Plane, and Screen Plane centre defined.

Fig.2b – An array of cameras arranged along the horizontal axis while pointing at the screen centre.

Fig.2c – A single camera moving along the track capturing the scene at designated intervals while pointing at the screen centre.

Fig.3a – A replicated 3D environment.

Fig.3b – A replicated 3D environment (demonstrating the effect of changing the view distance).

Fig.3c – A replicated 3D environment (demonstrating the effect of moving the camera to the left).

Fig.3d – A replicated 3D environment (demonstrating the effect of changing the FOV).

Fig.4 – shows an image sequence after reversing.

Fig.5 – shows when the plane of the CCD is not in parallel to the plane of the scene.

Fig.6 – shows that the Distance 0 is taken as unity.

Fig.7a – a front view of the HPO capture system.

Fig.7b – Front view of the HPO capture system with the track rotated along the z-axis.

Fig.8a – A typical image with keystone distortion.

Fig.8b – The corresponding image of Fig.8a after compensating for keystone.

Fig.8c – The corresponding image of Fig.8b after stretching.

Fig.9 – A system according to an exemplary embodiment.

DETAILED DESCRIPTION

A method 100 of keystone correction of a first digitized image according to an exemplary embodiment is shown in Fig.1. At 102 the image is captured in a first environment. At 104 the original capture parameters are input. At 104 the virtual capture geometry is set up in the 3D virtual engine. At 106 the captured image sequence is temporally reversed. At 108 the reversed image sequence is sequentially pasted into the virtual slate. At 110 the reversed image sequence is pasted on the slate and is captured using a camera path that replicates the original camera path.

As shown in Fig. 10, because of the reversal of the image sequence each image will be recaptured on the opposite side but the same distance from the centre line 1000. The centre line 1000 may be a first axis coincident with the origin 1002 of the slate or screen plane 1004 and is perpendicular to the slate or screen plane 1004. Thus for each image the second virtual camera location 1006 is reflected about the centre line or first axis 1000 compared to the first camera location 1008 in the original capture system.

There may be various 3D capture systems used for capturing information for 3D scene reproduction. The characteristics of the capture systems may depend on the characteristics of the 3D display. Examples are given below.

The 3D reproduction system may employ a Horizontal-Parallax-Only (HPO) approach. For the HPO 3D reproduction system, the 3D perspective is captured and retrieved along the horizontal axis 200 (**Fig.2a**). The sequence of images is commonly captured by one of the following methods:

1. An array of cameras 202 arranged along the horizontal axis 204 while pointing at the screen centre 206 (**Fig.2b**).
2. A single camera 208 moving along the track 210 capturing the scene at designated intervals while pointing at the screen centre 206 (**Fig.2c**).

Both methods produce a sequence of images 212 representing the light field of the original scene along the horizontal axis.

The following parameters of the original capture system are recorded:

- i) Lens Field-Of-Vision (FOV)
- ii) View Distance (from camera to screen centre)
- iii) Track length and function
- iv) Image resolution
- v) Number of images in the image sequence.

A computer platform 900 such as shown in Figure 9 may be programmed according to the exemplary embodiment. For example it may use software such as, for example, 3dsMax, Maya, or Microsoft DirectX 9.0c SDK running on the .NET platform. The platform includes an input device 902 to allow the above parameters to be entered or they may be stored in storage 904. The storage 904

stores the sequence of images. A processor 906 then executes the software to create a virtual 3D environment 908, replicating the original capture setup which can be shown on a 2D display 909, to allow feedback from parameter entry for the input device 902.

A virtual camera 910 has with the same attributes as the original camera, pointing at the centre of the scene. A virtual slate 912 replicates the screen plane and placed at the correct distance from the camera track. A ruler 914 on the slate is for sizing the slate correctly. Based on the known FOV and View Distance, the slate can be correctly sized.

A replicated 3D environment with the ruler correctly sized is shown **(Fig.3a, b, c, d)** according to the exemplary embodiment and demonstrates how the parameters can be entered to replicate different capture and scene geometries. Once the geometry has been set up the processor 906 can process the original frames, to produce a keystone corrected sequence of frames.

As an alternative, the single camera moving along a track can also be substituted by an array of cameras arranged in designated intervals. Both these methods capture the same image sequence.

Assuming the original image sequence is numbered in ascending order from left to right, e.g. frame 0, 1, 2, 3, ... 99 (assume 100 frames in total), the image sequence 400 is reversed **(Fig.4)**. That means, in the reversed sequence, the original frame 0 will now be renamed frame 99, the original frame 1 will now be renamed frame 98, and so on.

There will be as many camera positions as there are images in the image sequence. If the original images were captured with the camera starting from the left, the system captures the first image in the reversed image sequence after

placing the image on the slate using the original camera sequence. The camera will now move to the next position while the image on the slate is replaced with the next image in the image sequence. This process continues for the length for the image sequence.

As an example, an actual keystone distorted image 800 is shown in **Fig.8a** and the corresponding corrected image 802 is shown in **Fig.8b**.

This is, in effect, a reversal of the distortion by reversing the original capture process.

In a keystone distorted image, the width of any object may be less than if there was no keystone distortion in the image. This can be understood by observing that the plane of the CCD 500 is not parallel to the plane of the scene 802 (**Fig5**).

The image can be stretched to the correct width. The amount of stretch can be expressed as a ratio, s , where,

$$S_i = \text{Distance}_i / \text{Distance}_0$$

Where,

Distance $_i$ = Distance of cam $_i$ to the centre of the screen

Distance $_0$ = Distance of centre cam to the centre of the screen

See **Fig.6**. Distance $_0$ 600 is taken as unity.

With this, the keystone distortion may be corrected 804 as shown in **Fig.8c**.

While keystone distortion correction is most often required in HPO 3D reproduction, this invention is not limited to the horizontal-parallax scenario. Instead of the track 700 being placed in the horizontal axis only (**Fig.7a**), the track

can be tilted along the z-axis, so that it lies in the x-y plane 702 (**Fig.7b**). The keystone distortion will now have 2 components in 2 axes.

Once the keystone corrected sequence has been generated by the processor 906, it may be stored in storage 904 or may be output to a 3D display.

Correcting this distortion through geometrical transformation will prove challenging. However, this exemplary embodiment may be intuitive by simply reversing the image sequence and replicating the same environment and the same track. The distortion may be intuitively overcome.

In more complicated scenarios where the images are captured not in a straight-line but a complex plane, each of the cameras may be placed on the "opposite" side in the replicated 3D environment in order to correct the distortion.

Whilst exemplary embodiments of the invention have been described in detail, many variations are possible within the scope of the invention as will be clear to a skilled reader.

CLAIMS

1. A method of keystone correction of a first digitized image captured in a first environment comprising:
displaying the first image on a plane within a second virtual environment,
and
capturing a second image of the displayed image from a second camera location in the second virtual environment,
wherein the second virtual environment including a first axis coincident with the origin of the plane and perpendicular to the plane, the second camera location is reflected about the first axis to the first camera location.
2. The method of claim 1 wherein the second virtual environment replicates the capture and/or scene geometry of the first environment.
3. The method of claims 1 or 2 further comprising stretching the second image.
4. The method of claim 3 wherein the stretching is in a direction perpendicular to the first axis and in accordance with the distance of the second camera location from the origin.

5. The method of any of the preceding claims further comprising receiving parameters of the first environment input selected from the group consisting of:

- i) Lens FOV
- ii) Distance of camera to scene plane
- iii) Track length and function
- iv) Image resolution
- v) Number of images in the image sequence.

6. The method of any of the preceding claims wherein there is a sequence of first images captured in the first environment.

7. The method of claim 6 wherein the sequence of first images captured in the first environment are displayed on the plane in reverse temporal order, and the temporal sequence of the second camera locations is the same as the temporal sequence of the first camera locations.

8. The method of any of the preceding claims wherein the size of the image on the plane is sized according to a capture window in the first environment.

9. The method of claim 3 wherein the second camera location is on a line parallel to the plane, and the second image is stretched in one dimension according to ratio of the distance from the intersection of the line and the first axis to the origin compared to the distance from the second camera location to the origin.

10. The method of claim 5 where capturing the second image includes a virtual camera that replicates a camera in the first environment, the virtual camera virtually capturing the first image, depending on the parameters.
11. The method of any of the preceding claims further comprising capturing the first image using a linear array of cameras.
12. The method of any claims 1 to 10 further comprising capturing the first image using a camera translatable in at least one dimension.
13. The method of any of the preceding claims wherein the first and second camera locations are one dimensional.
14. The method of any of claims 1 to 10 wherein the first and second camera locations are two dimensional, and a rectangular array of cameras is used to capture the first image.
15. The method of any of the preceding claims wherein the first and second camera locations lie on a capture plane, the capture plane being spaced from and parallel to the plane.
16. The method of any of the preceding claims wherein the first environment is a real world environment.

17. The method of any of claims 1 to 15 wherein the first environment is virtual and the first image is computer generated.

18. A system for correcting keystone distortion in a digitised image comprising:

a first camera located at a first camera location in a first environment, the first camera configured to capture a first image of an object,

a plane in a second virtual environment, the plane configured to display the first image in the second virtual environment,

a second camera located at a second camera location in the second environment, the second camera configured to capture a second keystone corrected image of the plane including the first image displayed thereon.

19. The system of claim 18 wherein the second camera location is reflected about a centre line to the first camera location.

20. The system of claim 19 further comprising a processor configured to control the cameras and storage configured to store the images, wherein the processor is further configured to stretch each image according to the distance of the second camera location from the centre line.