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PTO/SB/16 (2-98)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

INVENTOR(S)					
Given Name (first and middle [if any])		Family Name or Surname		Residence (City and either State or Foreign Country)	
Shmuel		Peleg		Jerusalem, ISRAEL	
Robert Samuel		Rosenschein		Jerusalem, ISRAEL	
<input type="checkbox"/> Additional inventors are being named on the ___ separately numbered sheets attached hereto					
TITLE OF THE INVENTION (280 characters max)					
A System for the Recording and Playback of Stereoscopic Images and Video ^{Panoramic}					
Direct all correspondence to: CORRESPONDENCE ADDRESS					
<input type="checkbox"/> Customer Number		<input type="text"/>		Place Customer Number Bar Code Label here	
OR Type Customer Number here					
<input checked="" type="checkbox"/> Firm or Individual Name		Shmuel Peleg			
Address		45 Bar Kokhva St.			
Address					
City		Jerusalem		State	ZIP 97892
Country		ISRAEL		Telephone	Fax
				+972-2-6585236	+972-2-5322469
ENCLOSED APPLICATION PARTS (check all that apply)					
<input checked="" type="checkbox"/> Specification Number of Pages		10		<input checked="" type="checkbox"/> Small Entity Statement	
<input type="checkbox"/> Drawing(s) Number of Sheets		<input type="text"/>		<input type="checkbox"/> Other (specify) <input type="text"/>	
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (check one)					
<input checked="" type="checkbox"/> A check or money order is enclosed to cover the filing fees				FILING FEE AMOUNT (\$)	
<input type="checkbox"/> The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: <input type="text"/>				75.00	
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
<input checked="" type="checkbox"/> No.					
<input type="checkbox"/> Yes, the name of the U.S. Government agency and the Government contract number are: _____					

Respectfully submitted,

SIGNATURE

Shmuel Peleg

TYPED or PRINTED NAME

Shmuel Peleg

TELEPHONE

+972-2-658-5236

Date

9/17/98

REGISTRATION NO.

(if appropriate)

Docket Number:

Petition for Inter Partes Review of
U.S. Pat. No. 6,665,003

IPR2013-00326

EXHIBIT

Sony-1109

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C., 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, D.C., 20231.

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<h1 style="margin: 0;">FEE TRANSMITTAL</h1> <p style="font-size: small; margin: 0;">Patent fees are subject to annual revision on October 1 These are the fees effective October 1, 1997. Small Entity payments <u>must</u> be supported by a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12 See 37 C.F.R. §§ 1.27 and 1.28</p>		Complete if Known	
TOTAL AMOUNT OF PAYMENT (\$) 75.00		Application Number	
		Filing Date 9/17/98	
		First Named Inventor Shmuel Peleg	
		Examiner Name	
		Group / Art Unit	
		Attorney Docket No.	

METHOD OF PAYMENT (check one)	FEE CALCULATION (continued)																																																																																																																																																																																	
<p>1. <input type="checkbox"/> The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:</p> <p>Deposit Account Number <input style="width: 150px;" type="text"/></p> <p>Deposit Account Name <input style="width: 150px;" type="text"/></p> <p><input type="checkbox"/> Charge Any Additional Fee Required Under 37 C.F.R. §§ 1.16 and 1.17 <input type="checkbox"/> Charge the Issue Fee Set in 37 C.F.R. § 1.18 at the Mailing of the Notice of Allowance</p> <p>2. <input checked="" type="checkbox"/> Payment Enclosed: <input checked="" type="checkbox"/> Check <input type="checkbox"/> Money Order <input type="checkbox"/> Other</p>	<p>3. ADDITIONAL FEES</p> <table border="1" style="width: 100%; border-collapse: collapse; font-size: x-small;"> <thead> <tr> <th>Large Entity Fee Code</th> <th>Small Entity Fee Code</th> <th>Fee Description</th> <th>Fee Paid</th> </tr> </thead> <tbody> <tr><td>105</td><td>130</td><td>205</td><td>65</td><td>Surcharge - late filing fee or oath</td><td></td></tr> <tr><td>127</td><td>50</td><td>227</td><td>25</td><td>Surcharge - late provisional filing fee or cover sheet.</td><td></td></tr> <tr><td>139</td><td>130</td><td>139</td><td>130</td><td>Non-English specification</td><td></td></tr> <tr><td>147</td><td>2,520</td><td>147</td><td>2,520</td><td>For filing a request for reexamination</td><td></td></tr> <tr><td>112</td><td>920*</td><td>112</td><td>920*</td><td>Requesting publication of SIR prior to Examiner action</td><td></td></tr> <tr><td>113</td><td>1,840*</td><td>113</td><td>1,840*</td><td>Requesting publication of SIR after Examiner action</td><td></td></tr> <tr><td>115</td><td>110</td><td>215</td><td>55</td><td>Extension for reply within first month</td><td></td></tr> <tr><td>116</td><td>400</td><td>216</td><td>200</td><td>Extension for reply within second month</td><td></td></tr> <tr><td>117</td><td>950</td><td>217</td><td>475</td><td>Extension for reply within third month</td><td></td></tr> <tr><td>118</td><td>1,510</td><td>218</td><td>755</td><td>Extension for reply within fourth month</td><td></td></tr> <tr><td>128</td><td>2,060</td><td>228</td><td>1,030</td><td>Extension for reply within fifth month</td><td></td></tr> <tr><td>119</td><td>310</td><td>219</td><td>155</td><td>Notice of Appeal</td><td></td></tr> <tr><td>120</td><td>310</td><td>220</td><td>155</td><td>Filing a brief in support of an appeal</td><td></td></tr> <tr><td>121</td><td>270</td><td>221</td><td>135</td><td>Request for oral hearing</td><td></td></tr> <tr><td>138</td><td>1,510</td><td>138</td><td>1,510</td><td>Petition to institute a public use proceeding</td><td></td></tr> <tr><td>140</td><td>110</td><td>240</td><td>55</td><td>Petition to revive - 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SUBMITTED BY				Complete (if applicable)	
Typed or Printed Name		Shmuel Peleg		Reg. Number	
Signature		Shmuel Peleg		Date	9/17/98
				Deposit Account User ID	

Burden Hour Statement. This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

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**STATEMENT CLAIMING SMALL ENTITY STATUS
 (37 CFR 1.9(f) & 1.27(b))--INDEPENDENT INVENTOR**

Docket Number (Optional)

Applicant, Patentee, or Identifier: Shmuel Peleg and Robert Samuel Rosenschein

Application or Patent No.: _____

Filed or Issued: 9/17/98

Title: A System for the Recording and Playback of Stereoscopic Images
and Video ^{Panoramic}

As a below named inventor, I hereby state that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

☐ the specification filed herewith with title as listed above.

☒ the application identified above.

☐ the patent identified above.

I have not assigned, granted, conveyed, or licensed, and am under no obligation under contract or law to assign, grant, convey, or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern, or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

☒ No such person, concern, or organization exists.

☐ Each such person, concern, or organization is listed below.

Separate statements are required from each named person, concern, or organization having rights to the invention stating their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

Shmuel Peleg

NAME OF INVENTOR

Shmuel Peleg

Signature of inventor

9/17/98

Date

Robert Samuel Rosenschein

NAME OF INVENTOR

Robert S. Rosenschein

Signature of inventor

9/17/98

Date

NAME OF INVENTOR

Signature of inventor

Date

A System for the Recording and Playback of Stereoscopic Panoramic Images and Video

Shmuel Peleg and Robert Samuel Rosenschein

This application describes a system that enables the recording and playback of panoramic stereoscopic video and still images for use in immersive reality applications. Both the source images and the panoramic images can be still pictures or moving pictures. The viewer will need a special device for viewing the panoramic images. Such a device can comprise of one of the existing special stereo glasses: with color filters or with polarizing filters, or with shutters, using one of several existing methods to encode a stereo image-pair in a single image or screen. Also, it can be a display device that will deliver the appropriate image to each eye (e.g. using a stereoscopic head-mounted-display, HMD). In addition, a pointing device will indicate the desired field of view. The pointing device can be a mouse, a sensor detecting the direction of the head or eyes, or any other pointing device. The system can serve simultaneously several viewers, each possibly observing a different area of the scene.

1. Panoramic Images

A panorama is an image having a wide field of view, up to a full 360 degrees. Panoramas can be captured or generated in several ways, among them:

- ◆ By using a single camera and some kind of a mirror (conical, spherical, hyperboloidal, paraboloidal) [1]. Through the mirror a single image can view the entire scene, or at least a very large field of view.
- ◆ By using multiple cameras, or one rotating camera, and stitching their images into a single panorama (also called “mosaicing”) [2,3].
- ◆ Synthetic generation of a panoramic image given a scene model and a camera model.

It is common that each panorama has a single point of view (POV), also called the “center of projection”. The panorama can be viewed as a projection of the scene onto a cylinder or a sphere through this POV. It is necessary to have a single POV in order to create mathematically correct narrow-field-of-view images from the panoramic image. A panorama can cover any part of the viewing sphere, up to the entire viewing sphere. The images treated in this application can be still images or moving images, and wherever the term “image” is used, it should also be understood as a “video stream”.

1.1. Viewing a Panorama

In order to view a panorama, the desired viewing location is selected by some pointing device, and the viewing region is projected onto a plane to have the look of an ordinary picture. The projection into a planar image is needed as a panorama is usually represented in spherical or cylindrical coordinates [1, 4].

1.2. The Problem with Panoramic Stereo Images

At first glance, creating panoramic *stereoscopic* images seems some sort of contradiction. Every single image, be it ordinary picture or a panoramic picture, is taken from ap-

proximately a single point of view. A stereo pair is comprised of two images taken from two different points of view, corresponding to the distinct locations of the two eyes.

Assume we have two panoramic images, taken from two different locations (POVs) corresponding to the locations of the eyes. If we select in each panorama a viewing direction perpendicular to the line connecting the two POVs, then we could view the two images of the two selected regions as a stereoscopic pair. However, the two images will fail to give stereo perception in a viewing direction, which is in the direction of the line connecting the two POVs. Images from two cameras, one behind another, do not give stereo perception. To create 3D information from panoramic images it is suggested in [7] to create several panoramic images from different locations, and compute the 3D information of every scene point from its location on each of the panoramic images. But even a complete 3D model does not give an immediate panoramic stereo. If such a 3D model is given, for every desired viewing direction two images should be generated, one for each eye, by a process called “rendering”. Rendering is a very elaborate process, which today can only be performed by very expensive special purpose hardware.

In spite of this apparent contradiction, we propose methods for construction panoramas that enable such stereo viewing. The proposed methods create once two panoramas, and from these two panoramas images are generated for the two in a simple warping process, without the need for rendering.

2. Recording Stereoscopic Panoramic Images

This invention presents several approaches to the creation of panoramic stereo images. In addition to recording images, the recording “camera rig” can optionally also record its own location and/or orientation using devices such as a GPS, an inertial tracker, or a magnetic pickup to sense natural or artificial magnetic fields, etc. The location and orientation of the rig, together with the state of the pointing device, can be used to compute the region of the panorama viewed by the viewer. The general scheme of the process is described in Figure 1.

Images from the image source 100 are used by the panoramic creation process 101 to generate two stereo panoramas, L-Panorama 102 and R-Panorama 103. The image generation process 104 gets from the pointing device 107 the desired viewing direction, and generates from the two panoramas two images: The L-Image 105 is created from the L-Panorama 104 and is designated for the left eye; the R-Image is created from the R-Panorama and is designated for the right eye. Both are images delivered to the eyes of the viewer 108, who also manipulates the pointing device 107. Optionally, the image generation process 104 also gets from unit 109 the camera position, and will deliver images at a direction that is computed from both the camera position and the pointing device. As an example, such a process can keep the image stable even when the camera rig is rotating.

The image source 100 is detailed in Figure 2. Images can come from at least one of the following options: The set of cameras organized on a camera rig 110; they can also come from a moving camera 111, or from rendering a 3D representation of the scene 113. The 3D representation can be a synthetic scene model 112, or can be computed in step 115 from images of the scene using some other stereo process like the “vertical stereo” 114. For images coming from a moving camera, the camera position can be obtained by unit 109 from sensors tracking the cameras, or can be computed from the images themselves.

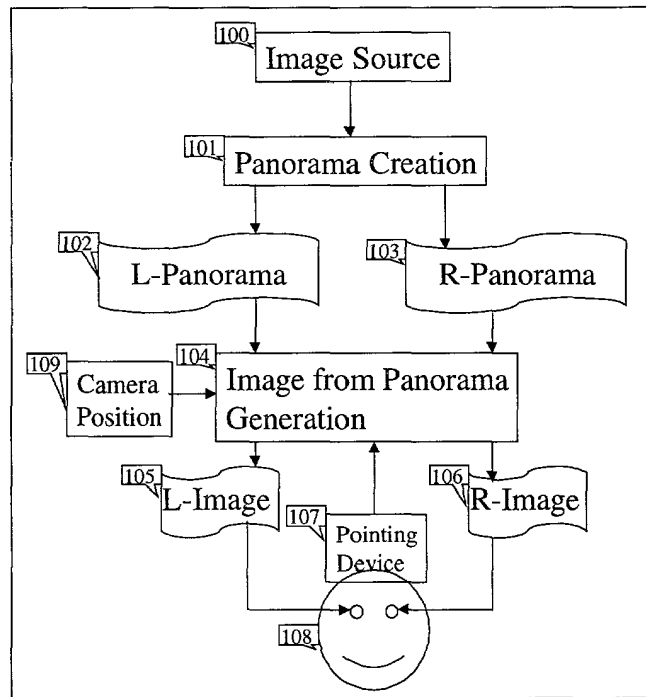


Figure 1: The Overall Stereo Panorama Process

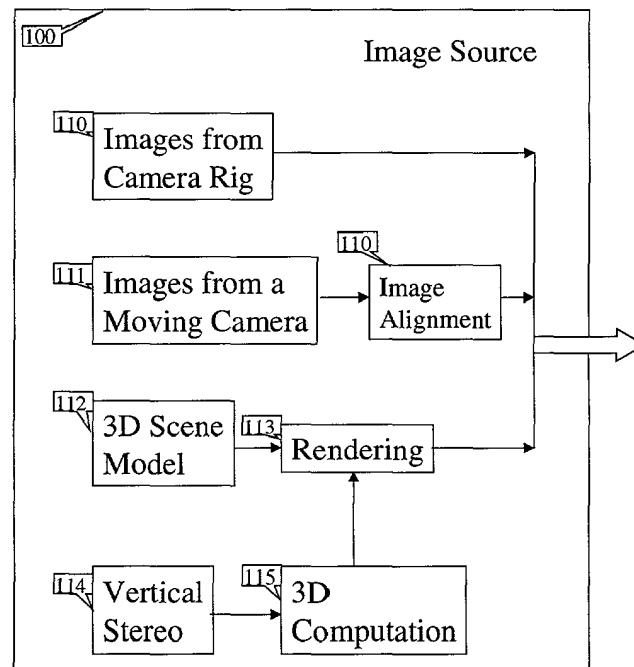


Figure 2: Possible Image Sources. This module provides the mosaic generation process with the images and their relative positions.

3. Option 1: Cameras on a Ring

In this option, the recording device is a camera rig comprising of several cameras arranged on an approximately circular ring. The cameras each point in a direction approximately perpendicular to the ring, but such that their fields of view (FOV) overlap. One possible setup of this arrangement is in a band or a headset worn on the person's head like a crown or halo. See Figures 3 and 4. The cameras may be distributed evenly around the ring, or may be closer together at some preferred directions.

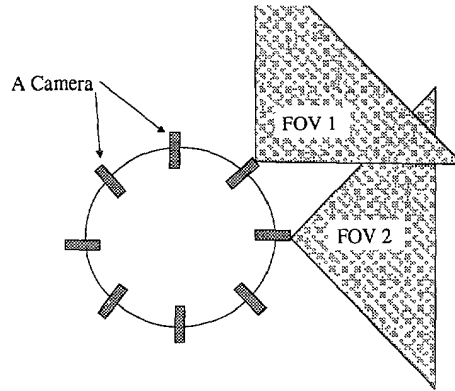


Figure 1: View from above of the stereo-panorama camera rig

Note that in this arrangement the cameras do not share the same POV. This follows, for example, the work in [8] that created panoramic images from a moving slit. Since the slit in [8] is translating, the panoramas are necessarily generated from images having different POVs. Also in [3], the images from which the mosaic is constructed do not necessarily share the same POV.



Figure 4. A person wearing the stereo-panorama rig.

3.1. Creating Stereoscopic Panoramic Images

The panorama-generation system creates and stores a pair of panoramic stereoscopic images for suitable playback. One panoramic image is created for each eye. The input to this process are the images contributing to the panoramic images, as well as the relative positions of the cameras or the images.

Creation of regular panoramic images usually takes a strip from the center of each image, and combines all the strips into a large panorama [3].

To create a pair of stereoscopic panoramas, each panoramic image should be taken from a different point of view, corresponding to the two different point of views of the two eyes. For panoramic stereoscopic images, this can be achieved by taking strips from different locations of the original images. For example, one panoramic image can be created from strips taken from the left side of the original images. This panorama will have the images for the right eye, to be called the R-Panorama. A second panoramic image will be created from strips taken from the right side of the original images. This panorama can correspond to images for the left eye, to be called the L-Panorama.

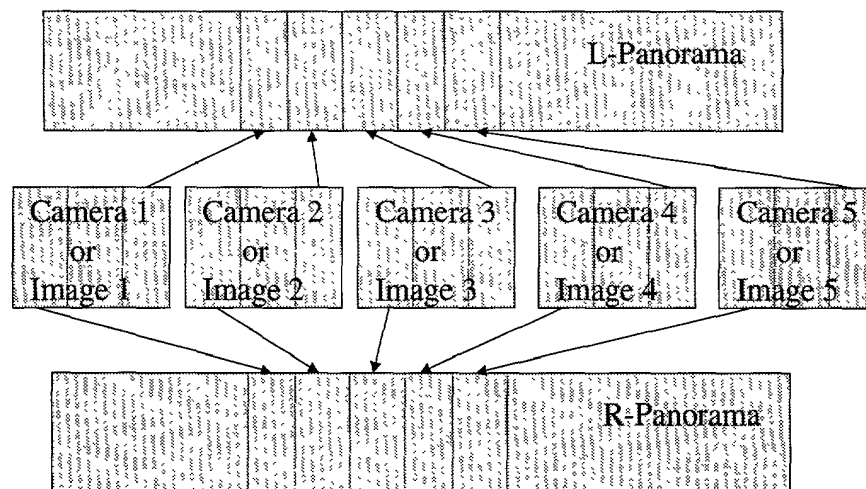


Figure 5. An Example for creating a pair of stereo panoramas from a set of cameras comprising a camera rig. Rather than a set of cameras, the two panoramas can also be constructed from a moving camera. Strips for the L-Panorama are taken from the right side of the images, and strips for the R-Panorama are taken from the left side of the images.

3.2. Playback

The playback device consists of three distinct parts: (1) a pointing or directional orientation device, (2) a system to take the selected region from the panoramic images and transform them to planar images for the display, and (3) a stereo viewing system, such as a set of stereoscopic video head-mounted display, where a different image can be delivered to each eye.

As the viewer moves the pointing device, e.g. moving his or her head, the two stereoscopic image which correspond to the selected direction are extracted from the two panoramic images, and are projected on the internal screens. This gives the viewer a stereo view in the desired direction.

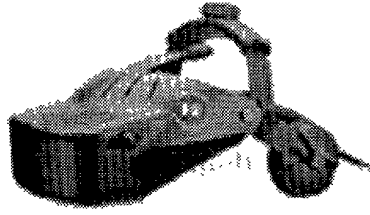


Figure 6. Stereo immersive reality playback headset.

3.3. Viewing Modes

The system can be used in two viewing modes, live viewing and pre-recorded viewing.

3.3.1. Live Viewing

In live viewing, the video images from all video cameras at the camera rig are combined in real-time to create the two stereoscopic video panoramic images. These two panoramic video images are sent to one or multiple viewing locations by any of several transmission mechanisms (television, cable, Internet, etc.). In the viewing area, the playback device can serve one or several viewers, each with the possibility of independently viewing a desired direction in the dynamic scene.

3.3.2. Pre-Recorded Viewing

With pre-recorded viewing, the images from all cameras, or synthetically generated images, are recorded for off-line creation and processing of the panoramic images, or the panoramic images can be created in real time and further recorded. The recording medium can be any medium used to record movies: from regular film, to magnetic videotape, to digital media like CD/DVD or computer file. The recording medium can be recorded and distributed, and can be played back as desired by the viewer using the playback device.

4. Option 2: Vertical Stereo

It is possible to create two stereoscopic panoramic images using multiple cameras and mirrors as described in [5], but where the possible rotation of the head will be around the axis connecting the two POVs. The system described in [5] comprises of two panoramic images taken from two POVs one above the other. This corresponds to a situation where the two eyes are one above the other, namely when the viewer is lying sideways. If we rotate this system so that the POVs will be side by side, corresponding to a sitting or a standing viewer, the possible rotation of the head for stereo viewing will be only up or down, but not sideways.

Let's call the stereo system as described in [5] a "vertical stereo". While vertical stereo is not suitable directly for viewing by a sitting person, and for sideways head motion, it has enough information to generate appropriate images. This can be done by *computing* the stereo correspondences between the points in the two panoramic images. This stereo correspondence can be done with any of several existing known methods. Once a stereo correspondence is achieved, new viewpoints can be further generated to correspond for any desired location of the eyes, and in particular sideways eye location. There are several known methods for the generation of new views, and an example is [6]. Alternatively, a 3D scene model can be computed, and desired images can be generated by rendering.

5. A Moving Camera in a Mostly Static Scene

We can also follow the traditional video mosaics [2,3,4], and create a mainly static stereo panorama from a single moving camera. However, while the original attempts for building panoramas recommended that video mosaics will be created from images taken by camera that are mainly rotating about their POV, stereo panoramas are created from images taken by cameras whose POV is changing. Images from translating cameras, or from cameras rotating about a point that is not their POV, may be used for creating static stereo panoramas.

5.1 A Rotating Camera

To create a stereo panorama from a rotating camera, the camera should be rotated around an axis that is behind the camera or in front of the camera. See example in Figure 7. The camera can either be a video camera or a still camera, collecting images of the scene with substantial overlap while rotating about its axis.

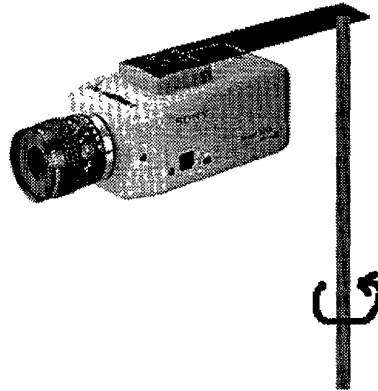


Figure 7: Camera arrangement for static Stereo Panorama

A sequence of overlapping images is taken while the camera is rotating about its vertical axis that is either behind or in front of the POV. The sequence of images from the rotating camera (as in Figure 7) is aligned using any of the known image alignment methods, or by measuring the exact rotation angle of the axis. After alignment, the creation of the pair of stereo panoramas is continued in a similar way to what is described in Section 3.1 and in Figure 5. There is one major difference between the mosaicing process of the fixed camera rig and the mosaic process of the rotating camera. In the fixed camera rig the images (or video streams) can be aligned in advance by knowing the relative position of the cameras and by performing initial calibration. In the case of the rotating camera, the alignment of the images is not known in advance, and alignment has to be computed between the frames.

Once the alignment between the frames is computed, the two stereo panoramas can be created by combining strips as described in Section 3.1 and in Figure 5. However, since the mutual displacement between the frames may be different for each pair of frames, the width of the strip used for mosaicing has to be determined for each frame. Examples for methods to determine the width of the strip are given in [3, 9]. In this configuration as well the strips for the L-Panorama are taken from the right side of the input images, and the

strips for the R-Panorama are taken from the left side of the input images. The distances between the centers of the strips going to the L-Panorama and the strips going to the R-Panorama can be computed in advance from the physical setup of the camera: the camera internal and external parameters, and the distance between the rotation axis and the POV.

5.2 A Translating Camera

Stereo panoramas can also be created from a translating camera. The major difference between mosaic creation from a translating camera and mosaic creation from a camera rotating about a vertical axis is the shape of the strip used. For images taken by a camera rotating about a vertical axis, the strips to be used are approximately straight. This is also the case for a translating camera that does not have a motion component in the forward or backward direction. However, when the camera motion has a forward or backward direction, the shape and the width of the strip should change, and its computation is described in [9].

As the other cases of the Stereo Panorama, the L-Panorama and the R-Panorama are constructed from strips taken from different places in the images. While the shape of the strips can be computed using methods described in [9], the distance between strips is still to be determined. This distance depends on the camera internal and external parameters, as well as the distance of the objects from the camera.

When a forward or a backward motion is involved, the panoramic images from strips taken from different areas in the images may be of different scale, since with such motion the scale of the object depends on their image location. If this is the case, the L-Panorama and the R-panorama should be rescaled to the same scale before stereo viewing.

6. Stereo Panorama from Synthetic Images

Stereo panoramas can be created not only from pictures of a real scene, but also from synthetically generated (e.g. computer-generated) images and models. A possible setup is described in Figure 8. Static or a dynamic panorama (cylindrical or spherical) is generated as follows:

Images are synthesized for cameras located on a circle. For normal effects the radius of the circle, r , should be approximately the radius of a human head, and the angle α should be such that $d = 2r \sin \alpha$ approximately equals the distance between the eyes. Let the angle β be approximately equal to angle α . At every position on the circle, an image is synthetically generated in two viewing directions, one for the L-Panorama and one for the R-panorama. The viewing direction for the L-Panorama should be pointing an angle of β to the right of the radial direction, and the viewing direction for the R-Panorama should be pointing at an angle of β to the left of the radial direction. All the images for the R-Panorama are mosaiced together to create the R-Panorama, and all the images for the L-Panorama are mosaiced together to create the L-Panorama. For special effects both the radius r and the angle β could be changed.

Since images are synthetically generated, they can be generated from any desired number of viewing positions. For highest quality, images can be generated densely enough so that each strip will have a width of one pixel. Also, to save rendering time, only the strips in image placed in the panorama have to be generated.

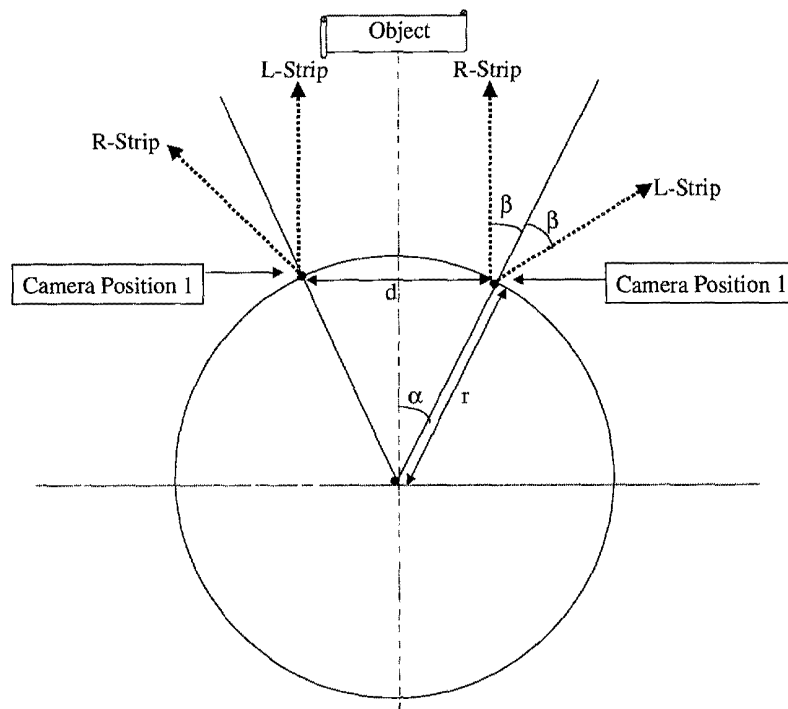


Figure 8: A diagram showing camera locations and viewing directions for the creation of stereo panoramas from synthesized images

7. Applications

The following areas are only a few of several target applications for the immersive reality technology medium using stereo panoramas. These applications may be:

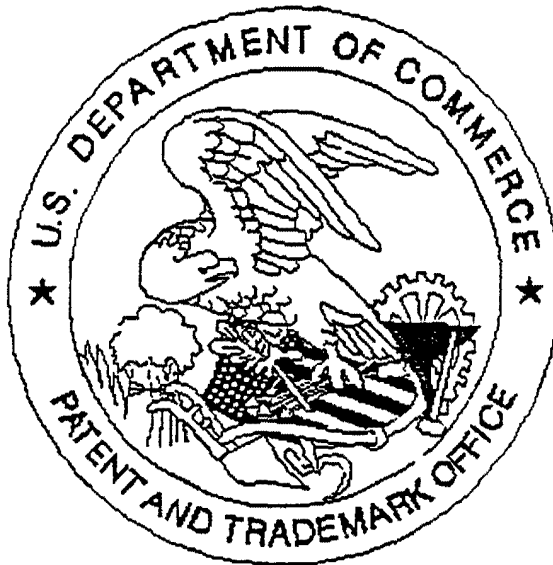
- ◆ Sports simulation and sports viewing: the camera rig may be installed in the playing field, or may actually be carried/worn by an athlete.
- ◆ Travel and tourism: giving the viewer a realistic visit to remote locations. This can take two forms: (1) “standard” visit to a popular tourist location (e.g. Paris, Tokyo, Disney World), or (2) exotic destinations (e.g. safari, Mt. Everest).
- ◆ Education. This can take two forms: (1) “standard” historical action (e.g. the court of Henry VIII), or (2) more exciting or dangerous situations (e.g. helicopter flight training, battle sequences).
- ◆ Drama, both passive (viewing) and interactive.
- ◆ Fantasy / adventure
- ◆ Children’s and adult entertainment, creation of cartoons.
- ◆ Marketing and sales (e.g. real-estate): giving a customer realistic stereo view of a property or neighborhood.
- ◆ Tele-operated robotics, where the camera rig is on the remote robot, and the viewer is the operator.

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