THREE-DIMENSIONAL IMAGING SYSTEM USING OPTICAL PULSES, NON-LINEAR OPTICAL MIXERS AND HOLOGRAPHIC CALIBRATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 60/533,384 filed Dec. 30, 2003, U.S. Provisional Application Ser. No. 60/533,134 filed Dec. 30, 2003, U.S. Provisional Application Ser. No. 60/533,305 filed Dec. 30, 2003, and U.S. Provisional Application Ser. No. 60/537,773 filed Jan. 20, 2004, the disclosures of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to three-dimensional imaging, and, more particularly, to an apparatus for providing a three-dimensional imaging system which includes a three-dimensional display, a two-dimensional and/or three-dimensional scanning device, and calibration equipment to calibrate the scanning device(s) and to simplify the combination of the images from one or more two-dimensional optical imaging devices into three-dimensional information. The display and the scanning device(s) both employ optical pulses and non-linear optics to display and record, respectively, a three-dimensional image.

BACKGROUND OF THE INVENTION

[0003] In obtaining and displaying images, more information for the viewer can be extracted if the image is three-dimensional rather than two-dimensional. Three-dimensional images provide the viewer with texture, depth color and position information. Three-dimensional images are more natural for humans to appreciate.

[0004] A volumetric three-dimensional imaging system displays images in a display volume which are acquired by a three-dimensional optical scanner or acquired by one or more two-dimensional optical scanners and converted to a three dimensional representation using holographic calibration. Light rays generated by the display at three-dimensional spatial positions appear as real objects to the viewer.

[0005] The prior art for three-dimensional displays includes two classes of displays: stereoscopic displays and swept volume "volumetric" displays. Stereoscopic displays are based on holographic or binocular stereoscopic technology that use two-dimensional displays to create a three dimension effect for the viewer. A shortcoming of stereoscopic displays is that they display spatial information from the perspective of only one viewer. Volumetric displays overcome this shortcoming by creating three-dimensional images in the display volume from voxels, the smallest distinguishable three-dimensional spatial element of a three-dimensional image. Volume displays satisfy depth cues such as stereo vision and motion parallax. Motion parallax is that phenomenon that a driver observes from his car when the terrain closer to him moves by faster than the terrain farther away.

[0006] In volumetric displays, the display volume is swept by a moving screen. The prior art for flat screen volumetric displays includes the LED arrays described in U.S. Pat. No. 4,160,973 to Berlin (the Berlin '973 Patent), the cathode ray sphere displays described in U.S. Pat. No. 5,703,606 to Blundell (the Blundell '606 Patent), the laser projection displays described in U.S. Pat. No. 5,148,301 to Batchko (the Batchko '301 Patent), and the rotating reflector displays described in U.S. Pat. No. 6,302,542 to Tsao (the Tsao '542 Patent). The prior art for curved screens includes the helical screen displays and the Archimedes' Spiral displays described U.S. Pat. No. 3,428,393 to de Montebello (the de Montebello '393 Patent).

[0007] There are two classes of holographic displays which utilize lasers or electron beams to generate illumination on moving screens of phosphor materials. The first class, which uses a laser or electron beam to excite a phosphor to emit light, includes the displays described in the Batchko '301 Patent, the Blundell '606 Patent, and U.S. Pat. No. 4,871,231 to Garcia (the Garcia '231 Patent). The second class uses intersecting lasers beams to generate illumination on moving screen using two stage excitement of photoluminescent media as described in U.S. Pat. No. 5,943,160 to Downing et al. (the Downing et al. '160 Patent) or photoionization of silicate Glasses as described in U.S. Pat. No. 6,664,501 to Troitski (the Troitski '501 Patent). The problem in both holographic display classes is the need for a high refresh rate of the voxels for real time displays. For a low resolution display of 500 by 500 by 500 voxels, with 20 refreshes each second to enable persistence of vision, data rates of several hundred megahertz to several gigahertz are required to refresh the display. High resolution (high definition) three dimensional display data rates are greatly reduced when voxels in the display can be accessed randomly without raster scanning and also when multiple voxels in the display can be accessed in parallel.

[0008] Another approach to color three-dimensional volumetric displays is the use of rotating light sources. Fiber optics implementations using this approach include the implementations described in U.S. Pat. No. 4,294,523 to Woloshuk et al. (the Woloshuk et al.'523 Patent) and in U.S. Pat. No. 3,604,780 to Martin (the Martin '780 Patent), which channel light using fiber optics to the moving screen. The rotating light source approach has problems connecting a large number of light sources to a moving screen and therefore their high definition displays are difficult to construct and maintain in operation. Implementations utilizing light sources on the moving screen such as the light emitting diodes (LEDs) of the Berlin '973 Patent result in complex implantations of light emitters and their associated active control electronics which are also included with the rotating screen.

[0009] Yet another approach to color three-dimensional volumetric displays uses projection techniques to display whole two-dimensional images on a moving screen such as a rotating reflector on a reciprocating screen (see the Tsao '542 Patent). While this approach has the advantage of high simultaneous transfer of image data to moving screen, its moving mechanism becomes mechanically more complicated as the size and thus the forces for moving the display increases. Furthermore, the accuracy of positioning of the projections in specific voxels decreases as the size of the display increases because of the increasing forces on the rotating screen and because the pointing error of the projection beams increases as display size increases.

[0010] The calibration of three-dimensional image acquisition equipment which includes optical recorders, especially for those configurations using multiple cameras, is a very time consuming process, as they require calibration for