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(54) **Title**: A SYSTEM FOR CAPTURING TRANSMITTING, AND DISPLAYING VOLUMETRIC DATA

(57) **Abstract**: A swept surface volumetric display device comprising of a actuator mechanism, wherein the actuator mechanism comprises of a power source and at least one electromagnetic coil driven rotational or linear motor, wherein the power source causes the rotational or linear motor to move the swept surface display back and forth, wherein the swept surface display is a projection screen onto which multiple slices of 3D geometry are projected every second, which through persistence of visions forms a 3D floating volumetric scene.

A SYSTEM FOR CAPTURING, TRANSMITTING, AND DISPLAYING VOLUMETRIC DATA

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States Provisional Patent Application No. 61/808,867, filed April 5, 2013 which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The invention relates to a field of displaying volumetric data.

BACKGROUND

[0003] This disclosure includes documentation of methods for achieving an optimal swept volume volumetric 3D display. Components of a swept volume 3D display typically include a fast moving screen with imagery projected on to it at high frame rates using an image generator which parses through a 3D scene and uses software to render a physical array of light in a given space, creating the perception of a 3D image present within a volume, displayed in sculptural form, and visible auto-stereoscopically with attributes similar to a physically embodied object occupying a volume with length, width and height. As the surface moves through physical space over time the imagery projected on to it modulates in correspondence to the incremental movement of a cross-section in the software representation of a 3D scene or object. A reciprocating swept volume approach, in contrast to a rotational swept volume, has similarities to a 3D printer which is composed of a structural build platform that moves in one direction upon which plastic is deposited on a two dimensional surface so as a physical 3D plastic object is formed by layering slice upon slice until an entire volume has been constructed. A reciprocating swept volume display digitally renders 3D visual imagery using light instead of plastic, and consists of a reciprocating screen onto which planes of light are projected in quick succession in such a way that persistence of vision enables multiples planes of light to be seen at the same time, and these multiple planes of light, together form 3D structures that have length, width and height, and can be viewed from multiple directions by multiple viewers at the same time, without visual aids such as glasses or goggles.

[0004] Methods of high speed projection are often described by use of the technologies identified with the terms SLM (surface light modulator), DMD (Digital Micro-mirror Device), MEMS (Micro Electro Mechanical System), or DLP (Digital Light Processing - a trademark of Texas Instruments) line of projector components. The source of display imagery provided to the projector may be a fixed location in hardware memory for non-interactive still or animated imagery, or for interactive imagery a dynamically updated hardware memory location or a signal delivered via digital video input cables generated in real-time by a central processing unit or graphical/general processing unit manipulated by a user via input device such as mouse, keyboard, touch pad, or motion tracking 3D object position sensing device.

[0005] There are several visual drawbacks to conventional swept volume displays that utilize axial rotating screens in continuous rotation with either a flat or helical curved surface. These drawbacks relate to the non-uniform distribution of addressable points of light, wherein the density of voxels vary throughout the volume. The variation in density can be attributed to such things as varying angular velocity relative to the center of rotation, step changes in the screen height and rounded edges. These attributes can create undesirable effects such as dead spots where voxels cannot be displayed, stretched geometry due to projected light hitting the screen tangentially and unwanted reflections.

[0006] Reciprocating swept volume mechanisms can better achieve a volumetric 3D display in contrast to other approaches because they provide an even consistency of display coverage within a volume through a sweep over time, they require less processor intensive slice calculations to reconstruct a volume, and have more direct synchronization correlation between screen positioning control signal and 2D video transmission to the screen. Additionally, a reciprocating actuation based swept volume display can more easily accommodate a rear projection system, which is more desirable than an apparatus that requires front projection because with rear projection, a viewer may look around the projected image volume and interact with a such a volume from above without obscuring the path of projected light from its source to its absorption on the moving screen surface.

[0007] The use of reciprocating swept volume mechanisms present difficulties in executionthat have traditionally minimized their practical usage. For example, the forces related to alternating movement are significantly increased as the volume size and refresh rates increase and require physical components made from materials with strength to hold up under stress from these forces as well as electrical voltage and current that can supply the power to propel a screen against these forces. These difficulties can, if unaddressed, limit the subject matter of 3D content that can be depicted with respect to object volume aspect ratio and size, as well as frequency of refresh to achieve persistence of vision for successful still object, animation, and interactive 3D volume rendering.

[0008] The force related challenges can be understood through an example wherein an 8 ounce screen with a length and width of 8 inches reciprocating through a stroke of 2 inches for an aspect ratio of 4:4:1 at 10 Hz to achieve 10 volumes per second. This is fast enough for persistence of vision to allow a viewer to perceive a 3D chess board, but is too slow to make the animation is look smooth, and at this rate, the screen must withstand a maximum of 3.12 pounds of force with accelerations up to 8.34 g-forces. Increasing the size of stroke to 8 inches for a 1:1:1 aspect ratio at 20 Hz creates a cubic aspect ratio with apparent flicker reduced to a level suitable for industry standard levels of interactive gameplay but at the same time increases the work required to a maximum of 67 pounds of force with accelerations up to 133 G-forces.

[0009] A conventional mechanism chosen to drive a reciprocating screen can use a crankshaft, such as the reverse of a car engine, to convert the rotational motion of a motor into reciprocating motion of a piston sliding through a guiding cylinder propelled by a linkage. Another approach is to lift the screen up and down through the attachment of 4 edges of the screen to 4 points on the edge of a disk or arm attached to 4 motors where the cycle of rotation moves the screen both up and down as well as side to side - wherein a rectangular screen may be reduced to having a projectable area of a square while expanding the size of the apparatus producing a greater minimum length than width. Another approach is to use a scotch yoke wherein the vertical motion of the attachment points is preserved while the horizontal motion is controlled by the restricted movement of the pins through a guiding slot and reciprocating sliding motion.

[0010] The drawback to the aforementioned approaches are that friction is created through the use of sliding parts and undesirable offsetting of a screen reduces the consistently projectable area of the screen and non-uniformly increases the minimum dimensions of the display area in relation to the total actuation area. These approaches rely solely on the direct driving mechanical actuation of motors pushing against the resistance of mechanism component weight, air resistance, gravity, and the friction of sliding parts.

[0011] Execution of a fast-refreshing large-volume deep-aspect-ratio rear-projection reciprocating-swept-volume display is difficult to achieve compared to the ease with which a slow-refreshing low-volume shallow-aspect-ratio front-projection reciprocating-swept-volume display. The novel techniques taught by this disclosure detail the effective construction of such a volumetric 3D display which has the attributes of the former, optimally designed system.

[0012] Our methods utilize harmonically tuned materials resonant with the frequency of motion in the system to provide assistance to the work performed by motors or electromagnetic coils to move a screen which convert kinetic energy exerted in one stroke/sweep direction to potential energy retained by the compression or expansion of in a spring, elastic material, or magnetic field that can be converted back to kinetic energy to assist the pull or push of the screen in the opposite stroke/sweep direction. This results in the lowest possible stress on the material components of the system allowing a reduced cost of materials - for example a thinner and lighter strut or motor linked arm made from plastic can be used in preference to a thicker and heavier strut/arm constructed from steel. Additionally, the electrical energy required to generate the kinetic energy in the screen can be reduced due to storage of energy in the springs. For example, if 50% of the kinetic energy is converted to potential energy and stored in the springs , then that's is a 50% saving on the cost of the power required to drive the motor or electromagnetic coil.

BRIEF SUMMARY

[0013] It is an object of the embodiment of the present invention to provide a device and method for displaying volumetric data as well as applying that technology to useful applications.

[0014] The methods of an embodiment of the present invention utilize harmonically tuned mechanisms and materials that resonate at a frequency of motion in such a way as to provide assistance to the work performed by motors and /or electromagnetic coils to move a screen which stores the kinetic energy exerted in one stroke/sweep direction as potential energy retained by the compression or expansion of in a spring, elastic material, or magnetic field and which can be converted back to kinetic energy to assist the pull or push of the screen in the opposite stroke/sweep direction. This results in the lowest possible stress on the material components of the system allowing a reduced cost of materials. For example, a thinner and lighter strut or motor linked arm made from plastic can be used in preference to a thicker and heavier strut/arm constructed from steel. Additionally, the electrical energy required to generate the kinetic energy in the screen can be reduced due to storage of energy stored in the springs. For example, if 50% of the kinetic energy is converted to potential energy and stored in the springs , then that is a 50% saving on the cost of the power required to drive the motor or electromagnetic coil.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 illustrates an example implementation of a screen movement being driven using a DC motor fed with an AC signal.

[0016] FIG. 2 illustrates an embodiment wherein the screen movement is driven by an audio frequency coil.

[0017] FIG. 3 illustrates an embodiment wherein the actuation of the screen uses a Brushless, Stepper or Linear Motor.

[0018] FIG. 4 illustrates an example of an embodiment utilizing harmonic resonance to amplify the screen movement.

[0019] FIG. 5 illustrates a system for synchronizing a projector and reciprocating screen using an audio signal in accordance with some embodiments.

[0020] FIG. 6 illustrates a system for synchronizing a projector and reciprocating screen using an encoded pixel in the video signal in accordance with some embodiments.

[0021] FIG. 7 illustrates a system for synchronizing a projector and reciprocating screen using positional feedback sensor in accordance with some embodiments.

[0022] FIG. 8 illustrates a system of capturing volumetric data in accordance with some embodiments.

[0023] FIG. 9 illustrates a system for volumetric video conferencing in accordance with some embodiments.

[0024] FIG. 10 illustrates a volumetric arcade game system in accordance with some embodiments.

DETAILED DESCRIPTION

[0025] In order to create a swept surface volumetric display, it is necessary to sweep a projection surface though a volume of space and display on it a multitude of slices of a 3D scene, where the timing of each projected slice ensures that it is displayed on the screen in a position relative to where it exists in the actual scene that is being displayed. The projection surface needs to move fast enough to create the experience of persistence of vision. The following section makes various claims about a number of techniques developed to reciprocate a projection surface in the form of a flat or slightly curved plane at the rate required to establish persistence of vision. These techniques are referred to as actuator mechanisms. A key physical constraint of an actuator mechanism is the force required to change its direction. In embodiments of the present invention, harmonic resonance is utilized to reduce the force required to change directions and enhance the efficiency and/or amplify the movement of the projection screen through the volume. A person skilled in the art would understand that the utilization of harmonic resonance is not a necessary condition for the actuator mechanisms to function, but it does enhance their efficiency and performance. In order to guarantee that the projected slices are displayed at the correct time, a number of solutions have been developed to synchronize the movement of the screen and the projection of each slice of data.

[0026] FIG. 1 – Example Implementation of Actuation of Screen Movement by Driving a DC Motor with an AC Signal. Components: 11A, 11B, 11C: springs, 12A, 12B: pulley, 13: motor, 14: spring anchor, 15: screen mount, 16: actuator housing, 17A, 17B: motor pulley, 18A, 18B: spring anchors, 19A, 19B: half pulleys, 20A, 20B: strings, 21: strut, 22: screen

[0027] An example implementation is described as follows: The mechanism consists of two resonant systems on each side of the device. Each resonant system consists of string 20A that is permanently affixed to spring 11A, is looped around pulley 12A, passes through the half pulleys 19A and 19B that are permanently affixed to strut 21, is looped around pulley 12B and is permanently affixed to string 11B. The ends of springs 11A and 11B are affixed to spring anchors 18A and 18B, respectively. One end of string 20B string is permanently affixed to strut 21, is looped around pulley 17A and permanently affixed to a point on pulley 17A and then looped around pulley 17B and is permanently affixed to spring 11C.

[0028] Springs 11A and 11B are tensioned so that they pull on string 20A which in turn pulls on half pulley 19A, applying force on strut 21 in an upward direction. Spring 11C is tensioned so that it pulls on pulley 17B, providing a force counterpoised to the force provided by springs 11A and 11B. This forms a resonant system.

[0029] The system operates by a current applied to the motor. When the motor turns, it applies force on the other elements of the system. In this example, the current oscillates at frequency X, causing the motor to oscillate at frequency X. This causes the system to oscillate so that the screen mount reciprocates in a vertical direction. The tension on the springs is adjusted so that the system is resonant at frequency X.

[0030] FIG. 2 – Actuation of Screen Movement by Audio Frequency Coil. Components: 22: screen, 201: screen support strut, 202: speaker cone, 203, speaker base.

[0031] FIG. 2 illustrates an embodiment of the actuation of the screen movement by an audio frequency coil. An audio frequency electromagnetic coil is connected to a projection screen wherein the kinetic energy generated by the electromagnetic coil is transferred either directly or through harmonic resonance to the projection screen.

[0032] One end of each screen support strut, 201, is permanently affixed to the speaker cone, 202, and to the screen, 22. A mirror, 204, is permanently affixed to a non-moving portion of the device and is angled so that light from a projector, 205, can be projected onto the screen, 22. The system functions when an alternating current is applied to the speaker cone, 202, causing the speaker cone to reciprocate. The screen then moves as the cone moves.

[0033] FIG. 3 – Actuation of Screen by Converting Rotary Motion to Linear Motion. Components: 22: screen, 301: screen support strut, 302A, 302B guides for linear slide, 304: crank, 306: crank wheel, 305: motor.

[0034] A motor, 305, turns a crank, 306, which in turns pushes a piston, 303, up and down and is guided by guide rails, 302A & 302B. The piston in turn pushes the screen, 22, up and down using the 3 or more support struts, 301.

[0035] FIG. 3 illustrates an embodiment of the actuation of the screen movement by Brushless, Stepper, or Linear Motor. The embodiment comprises of a synchronization output signal from a computer, a motor control circuit, a brushless DC motor, a linear to rotational converter, and a projection screen wherein the control circuit drives the motor in sync with the output. Rotational movement of the motor is converted to linear movement by the rotational to linear converter. Linear movement is transferred directly or through harmonic resonance to the projection screen.

[0036] FIG. 4 – Harmonic Resonance and Amplification of Screen Movement. Components: 22: screen, 401: spring, 402: rigid frame, 403: reciprocating driver.

[0037] The ends of a screen, 22, are attached to the ends of two springs, 401. The ends of the two springs, 401, are attached to a rigid frame, 402. A reciprocating driver, 403, applies motion to the rigid frame, 402. The system is tuned so that at the resonant frequency of the system, the extent of the movement of the screen can substantially exceed the extent of the movement of the reciprocating mechanism.

[0038] FIG. 4 illustrates Harmonic Resonance and Amplification of screen movement.

[0039] The embodiment comprises an electromagnetic actuator and a screen which is either suspended on springs in tension or affixed atop springs under compressions. The springs are specially designed to resonate at a known frequency. The electromagnetic energy source used to establish the harmonic movement of the screen and, to maintain its continuous motion could include but not be limited to electromagnetic coils, motors, other reciprocating mechanisms.

[0040] There are two core aspects to this embodiment: (1) Harmonic Assistance of the actuator mechanism, wherein the energy required to move the screen in a harmonic motion is much less than if it were not harmonic; and (2) Harmonic Amplification of the projection screen wherein the magnitude of the reciprocating screen can be greatly increased by increasing the energy levels of the driving force being used to initiate the harmonic motion.

[0041] Actuator Controllers. In order to create a swept surface volumetric display, it is necessary to project, or display, a multitude of cross-sectional slices of a 3D object on a moving screen, and those slices need to reach the screen at precisely the right time so that their position in three dimensional space at any instant, corresponds exactly to where the slice exists in the 3D object being displayed. Failure to display the slice at the correct time will lead to a 3D volumetric image that is partially or completely inverted or scrambled entirely. The following embodiments describe several methods of maintaining synchronization between a physical moving screen, and the slices of volumetric data being displayed on that moving screen. In order to create a volumetric display that is sufficiently detailed, it is necessary to project, or display more than a thousand slices per second.

[0042] FIG. 5 – Synchronizing a Projector and Reciprocating Screen Using an Audio Signal. Components: 501: Computer, 504: audio cable, 505: phase controller, 506: amplifier, 507: electromagnetic actuator, 503: video cable, 502: projection system, 22: screen.

[0043] The embodiment in FIG. 5 comprises of a computer (the computer equipped with a graphics engine and a signal generator), an actuator mechanism and a projection screen wherein the computer runs the graphics engine which triggers the signal generator to generate a synchronization waveform so as to control the actuator mechanism and synchronize the position of the projection surface with the video output. The signal generator may be the audio circuit on the computer or an external signal generator. The shape and phase of the waveform may be adjusted to correct for physical limitations of signal generator and actuator mechanism. Additional feedback may be provided by other mechanisms.

[0044] The computer, 501, generates a series of volume slices, and at the same time generates an oscillating sound wave whose peaks and troughs match the vertical position of the volume slices being displayed. The audio signal is sent out on an audio cable, 504, and through a mechanism for adjusting phase, 505, and then into an amplifier, 506, and then into an electromagnetically driven actuator, 507, which in turn reciprocates a screen, 22. At the same time, a video signal is sent on a cable, 503, to a video projection system, 502.

[0045] This embodiment uses one or more oscillating sine, triangle or other audio waveform that is created at the same time that the image slices are rendered by the graphics engine. The magnitude of the wave at any point in time corresponds to the vertical position of the slice of volumetric data being projected at that instance of time. The audio wave is generated at the same time as the volumetric data output from a PC or other hardware device and sent to an amplifier, where it it's amplified before being sent to an electromagnetic actuator where it is converted into physical movement. This sample can take any shape, and be a square wave, triangular wave, or any other shaped wave. In order to compensate for the effects of gravity on the moving screen, a positional sensor such as a rotary encoder or Hall Effect sensor or other type of positional sensor can be used to provide real-time feedback from the moving screen to the software generating the audio sample. The feedback can be analyzed to see how the actual movement of the screen compares to the desired movement as described by the audio sample. The audio signal can then be adjusted to make the up and down stroke of the moving screen as similar as possible.

[0046] The audio sample being sent to the actuator can also be phase-adjusted in real time either in software or with a hardware digital signal processor. This phase control is essential to compensate for variance in the time it takes audio and video to get from the PC to the screen. The variance can be influenced by such things as graphic buffer delays, cable length, analogue to digital conversion, digital to analog conversion and varying audio and video processing hardware. The delays inherent in any system are fixed and as such a phase correction control can be calibrated once for each device.

[0047] FIG. 6 – Synchronizing a Projector and Reciprocating Screen Using an Encoded Pixel in the Video Signal. Components: 601: Single encoded image slice with z value encoded in reserved pixel, 602: Timing pixel whose color either directly represents the zero-plane, or is directly proportional the position on the z axis that the image slice belongs to. 603: 3D Geometry being displayed.

[0048] The embodiment in FIG. 6 comprises of a computer, a graphics engine, a timing marker in the form of one or more specially encoded pixels, a projector, an actuator controller, a projection screen, a microprocessor and a microcontroller wherein the computer runs the graphics engine which outputs one or more timing markers encoded in a video signal. A microprocessor connected to the video cable reads the value of the timing pixel and translates the color of the encoded pixel into a value which indicates the point in time at which the projection plane should be at its lowest point. The microcontroller would then generate an audio signal to move the actuator and keep it perfectly in sync with the timing signal derived from the zero-frame marker pixel. An alternative to indicating when the lowest slice is being displayed is to use the reserved pixel to indicate the actual z value of the slice being displayed. For every slice being rendered, a number of bits could be reserved to hold an integer which represents the current position of the slice on the z -axis. If 8-bits were used for each slice, then 256 distinct z-plane values could be encoded. The pixels value would be extracted from the video by microprocessor, and used to constantly adjust a sync signal after every frame, rather than once every time a zero plane indicator was read.

[0049] The computer slices up 3D geometry, 603, into a multitude of image slices, 601, and those images slices have encoded in them a special timing pixel, 602, which can be used either to indicate that the current image slice is located on the zero plane or to directly indicate the position of the current slice on the z axis according to the color value of the pixel.

[0050] FIG. 7 – A System for Synchronizing a Projector and Reciprocating Screen Using Positional Feedback Sensor. Components: 701: Projection system, 702: Computer, 703: Digital Video Cable, 704: Reciprocating screen, 705: Distance between the sensor and the screen, 706: Positional Feedback Sensor.

[0051] The embodiment in FIG. 7 comprises a swept surface to be reciprocated using drive signal that does not originate in the volumetric graphics engine. A moving screen could be driven by any means, and the position of the screen could be measure thousands of times per second and that positional data fed back to a graphics engine where it would be used to dynamically generate the required data that was needed at the instant.

[0052] A screen, 704, is moved up and down by any means, a positional sensor, 706, measures the distance from it to the screen, at a rate of several thousand times per second. The positional data is sent to a computer, 702, where a computer program reads the positional data and creates a cross-sectional image that corresponds to that position in a volume of data, and then sends that image over a video cable, 703, to a projector, 701.

[0053] An example of a positional feedback device is a Rotary Encoder. A rotary encoder mounted on the shaft of a DC motor or Synchronous Motor, which was being used to drive a screen, would be used to pass the motor position back to the PC where the value would be used to adjust the video output to match the screen position at any time.

[0054] Another example of a positional feedback sensor is a Hall effect sensor. A Hall effect sensor attached to the moving screen or to the shaft of a motor that was being used to drive a screen would be used to pass the motor position back to the PC where the value would be used to adjust the video output to match that required.

[0055] Another embodiment uses software or hardware based control to adjust the phase of the sync signal being sent to the actuator. This phase control is used to compensate for variance in the time it takes the audio sync signal and projected volume slices to get from the computer to the screen. The variance can be influenced by such things as graphic buffer delays, cable length, analogue to digital conversion, digital to analogue conversion and varying audio and video processing hardware. The delays inherent in any system are fixed and as such a phase correction control can be calibrated once for each device.

[0056] Screen Material. In order to project color information onto a swept surface volumetric display using a single projector, it is necessary to use an LED light source that alternates between RED, GREEN and BLUE thousands of times per second. LED light sources are inherently less bright than other types of projector lamp such as HID (High intensity discharge). To compensate for the reduced brightness, it is necessary to use screen materials that increase contrast and perceived brightness.

[0057] An embodiment of the present invention enables enhanced visibility and contrast in a swept surface volumetric display through the use of a rear projection material such as 3M Vikuiti or Screen Innovations Black Diamond to increase contrast. These screen materials are unique as they utilize microbead technology that provides a bright, sharp picture at all angles. The screen materials are essentially achromatic (i.e.,very dark in color), and this has the effect that usage is not limited to environments with dark ambient lighting, thereby making the rear projection material considerably less noticeable to the human eye in a bright ambient light, and making the volumetric display's projected image data, in contrast, more visible to the human eye.

[0058] Previous implementations of volumetric displays primarily utilized a white front projection material, a frosted rear projection material bright in color, or a material that approaches transparency to project on to. The limitation of these approaches are their inability to provide a display image visible enough for practical application in common lighting conditions where ambient light reflects off the screen in areas other than where the projector is intended to perceive imagery. In the case of an almost transparent screen material a bright environment seen through the screen could wash out the projected imagery. Because achromatic microbead rear projection screen material absorbs light so as to appear opaque when not projected on to - it provides a contrasted backdrop for projected imagery as it blocks out the environmental light that would otherwise be seen behind a transparent screen. A white or frosted screen material would have it's projected imagery washed out by the scattering of indoor lighting or direct sunlight. Therefore a novel improvement to swept volume display is achieved through use of optical material components previously non obvious for those expert in the art to apply to such a reciprocating swept volume. Therefore our improvements expand the practical applications of swept volumetric display technology beyond the scope of darkly lighted environments to more common indoor conditions such as an office or advertising in retail locations, even outdoor display under direct sunlight is now possible using the methods taught herein.

[0059] One of the form factors used in an embodiment is a tiled large format volumetric display which could be used in public venues to display sporting games or other content. In these situations, the projection of volumetric data would be done from above, with a single projection system spanning a multitude of tiled actuator screens. An embodiment uses a high contrast screen such as Vutec SilverStar as a front projection surface in order to increase visibility in ambient lighting conditions.

[0060] Swept surface volumetric displays move a screen through the air and as such generate considerable air movement. This movement of air increases the load on the drive system, and also generates audible low frequency noise and vibration. An example of a solution involves the use of micro-perforating a screen in order to allow air molecules to pass through it, and subsequently reduce drag, vibration and noise levels.

[0061] As a screen is reciprocated, it is subject to alternating forces which can cause it to flex repeatedly, and this can result in unwanted noise. One solution to this problem is to make the screen slightly convex or concave. By adding this deformation to the screen, its mechanical properties are changed, making it stiffer and less likely to flex.

[0062] FIG. 8 – Capture, Transmission and Display on Volumetric Display. Components: 801: Computer, 802: Room or open space, 803: Multiple depth sensing cameras pointing inwards to capture all side of the subject simultaneously, 804: Swept surface volumetric display.

[0063] The embodiment shown in FIG. 8, uses one or more depth sensing cameras, such as Microsoft Kinect™, to capture animated 3D geometry of a scene which could include one or more person. The animated data could then be either recorded or transmitted over the internet or other digital connection to a volumetric display, where the data would be displayed, thus recreating the original scene at a remote destination. The data being captured could be saved as raw data or converted into images that contained both color information and depth information side by side. The capture of the data could be done both in a studio setting, using rigs to hold the depth sensors in a fixed configuration, or alternatively as part of a portable device to enable somebody to capture volumetric data outdoors or in any non-studio environment

[0064] The depth sensing cameras, 803, capture 3D data that maps the surfaces of all the objects visible in the room or open space and sends that data to a computer, 801, where it is converted into 3D Volumetric Data and either saved to memory or storage device, or displayed directly on a volumetric display, 804.

[0065] As well as displaying computer generated volumetric data, it is also possible to use a volumetric display to enable the projection of data captured from real-life subjects using a variety of capture techniques. There are a number of different ways of preparing this type of data to be used for the creation of volumetric video. Here, the term "Voxie" (voxel + movie) is used to describe a volumetric scene that has been created from motion captured, or 3D scanned techniques.

[0066] FIG. 9 – A System for Volumetric Video Conferencing. Components: 901: Depth sensing camera, 902: Computer.

[0067] An embodiment of the present invention, shown in FIG. 9, uses a depth sensing camera, such as Microsoft Kinect™ or other depth sensing cameras, to record the color and depth information of a person's face or upper body and then to transmit that data over the internet to a remote location where it can be displayed volumetrically. A person skilled in the art understands that the depth sensing camera(s) is not limited to recording information solely about a person's face or upper body. By using two such setups at the same time, it is possible for two or more people who are separated geographically to share a volumetric 'voxie video' conference, like a holographic version of Skype. The capture and display of facial data could also be used in specific hardware products such as intercoms.

[0068] Another embodiment of the present invention is an internet based service for sharing volumetric data that can be streamed directly to a swept surface volumetric display. A user could record volumetric data using a depth camera(s) or record volumetric gameplay or other events and upload that recording to a website where they could edit and tag their data and share it with one or more people. Other people who owned volumetric displays would then be able to search for and view previously recorded volumetric data on their own displays.

[0069] The Depth Sensing Cameras, 901, record the depth data and color data from a subjects face or upper body and sends that data over a network connection to another computer which could be in another room, or another country, where the data is converted into volumetric data and displayed on a volumetric display.

[0070] FIG. 10 – Volumetric Arcade Game System. Components: 1001: Swept Surface Volumetric Display, 1002: Game controller. The volumetric display, 1001, would be located in the center of a device around which multiple people could stand or sit, and interact with the display using game controllers, 1002. The display could be illuminated from below using rear-projection techniques, or from above.

[0071] The embodiment of the present invention, as shown in FIG. 10, is a Multiplayer Volumetric Gaming system that enables multiple players to play the same volumetric game together. A swept surface volumetric display is situated in the center of a "cocktail cabinet" style arcade gaming table with game controls situated on each side.

[0072] Those skilled in the art understand that other setups can also be utilized. The game controls could include, but are not be limited to, joysticks, buttons, gesture control devices, 3D input devices, depth sensing cameras and microphones. The table could also include multiple configurations of input controllers such as two joysticks on each side to enable two players on each side to play together or alternatively for 4 players, each using two joysticks for a different game control style. Other gaming variations and setups can also be used.

[0073] An embodiment of the present invention, the Voxie Kiosk, uses a swept surface volumetric display where high speed cross-sectional images are projected onto a rear projection material that is housed in an enclosure that is not visible to the players. Unlike previously described techniques, this invention does not sweep the projection screen through space, and instead sweeps a large lens or parabolic mirror beneath the projection screen, resulting in a floating 3D holographic apparition appearing in the space between the two players.

[0074] Another embodiment of the present invention, the Vxbx Home Edition, incorporates a swept surface volumetric display and computer in a compact form factor that can be used at home, and placed on a table.

CLAIMS:

1. A swept surface volumetric display device, comprising;

an actuator mechanism, wherein the actuator mechanism comprises a power source and at least one DC motor,

a rotational to linear converter, wherein the power source causes the DC motor to rotate back and forth further causing the DC motor to act on the rotational to linear converter, and

a swept surface display, wherein the swept surface display is a projection screen reciprocated by the rotational to linear converter.

2. A device according to claim 1 wherein the rotational to linear converter moves the swept surface display either directly or through harmonic resonance.

3. A device according to claim 1 further comprising an audio frequency electromagnetic coil connected to the projection screen wherein the kinetic energy generated by the electromagnetic coil is transferred either directly or through harmonic resonance to the projection screen.

4. A device according to claim 1 further comprising

a synchronization output, and

a control circuit wherein the control circuit drives the motor in sync with the synchronization output.

5. A device according to claim 1 wherein harmonic resonance is used to assist or amplify the movement of the projection screen.

6. A device according to claim 1 further comprising;

a graphics engine, wherein the graphics engine triggers a signal generator to generate a synchronization waveform, wherein the synchronization waveform controls the actuator mechanism and synchronizes the position of the projection surface with a video output.

7. A device according to claim 6 further comprising a timing marker, wherein the graphics engine encodes a timing marker in the video signal to indicate the vertical position of a data slice being projected.

8. A device according to claim 7 further comprising an optical sensor, wherein the optical sensor reads the position of a timing voxel as it is displayed on the projection screen and provides feedback to an actuator controller.

9. A device according to claim 8 wherein the actuator controller will adjust the synchronization waveform to match the output from the projector.

10. A device according to claim 8 wherein the graphics engine adjusts the output to the projector to synchronize with the actuator controller.

11. A device according to claim 1 wherein the swept surface display is kept in sync with projected images slices using positional data received from a positional feedback device.

12. A device according to claim 1 further comprising a phase adjustment control, wherein the phase adjustment control adjusts the phase of the signal being sent to the actuator.

13. A device according to claim 1 wherein the swept surface display comprises a high contrast rear projection screen.

14. A device according to claim 13 wherein the high contrast rear projection screen comprises a substantially achromatic microbead material.

15. A device according to claim 1 wherein the swept surface display comprises a micro-perforated screen.

16. A Voxiecom system comprising;

at least one depth sensing camera wherein the depth sensing camera(s) captures 3D geometry,

a transmission unit, and

a screen movement device, wherein the transmission unit transmits the contents captured by the depth sensing camera(s) to the screen movement device.

17. A system according to claim 16 wherein the 3D geometry is at least one person.

18. A system according to claim 17 wherein a second volumetric display system is used with the volumetric display system to conduct a volumetric conference.

19. A system according to claim 16 further comprising;

a recording unit, wherein the recording unit records the contents captured by the depth sensing camera(s) and

a storage unit, wherein the storage unit stores the recorded content.

20. A Multiplayer Volumetric Gaming system comprising a swept surface volumetric display wherein the swept surface volumetric display is situated in the center of an arcade style gaming system.

Example implementation of Actuation of screen movement by driving a DC motor with an AC signal

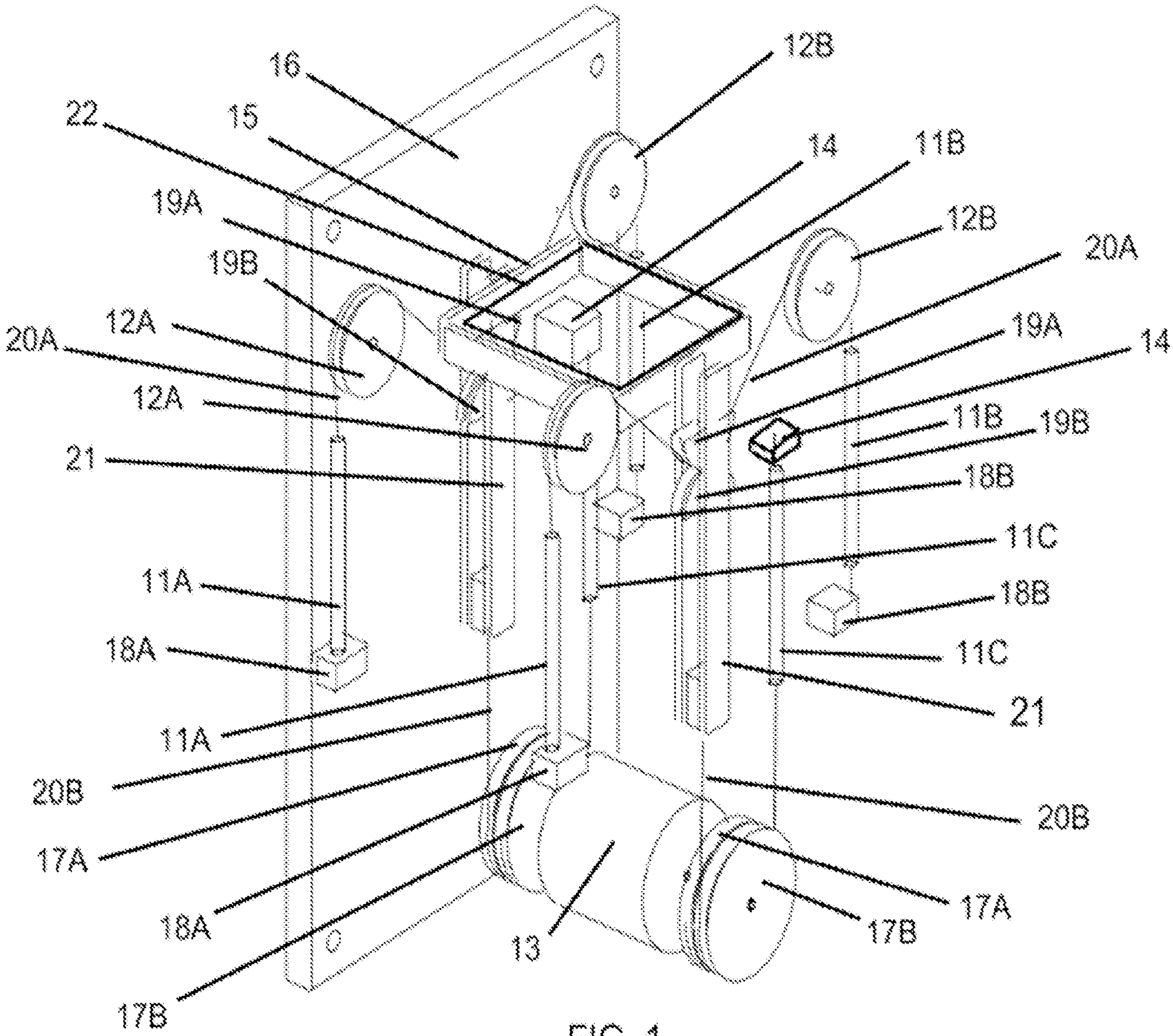

FIG. 1

Actuation of screen movement by audio frequency coil

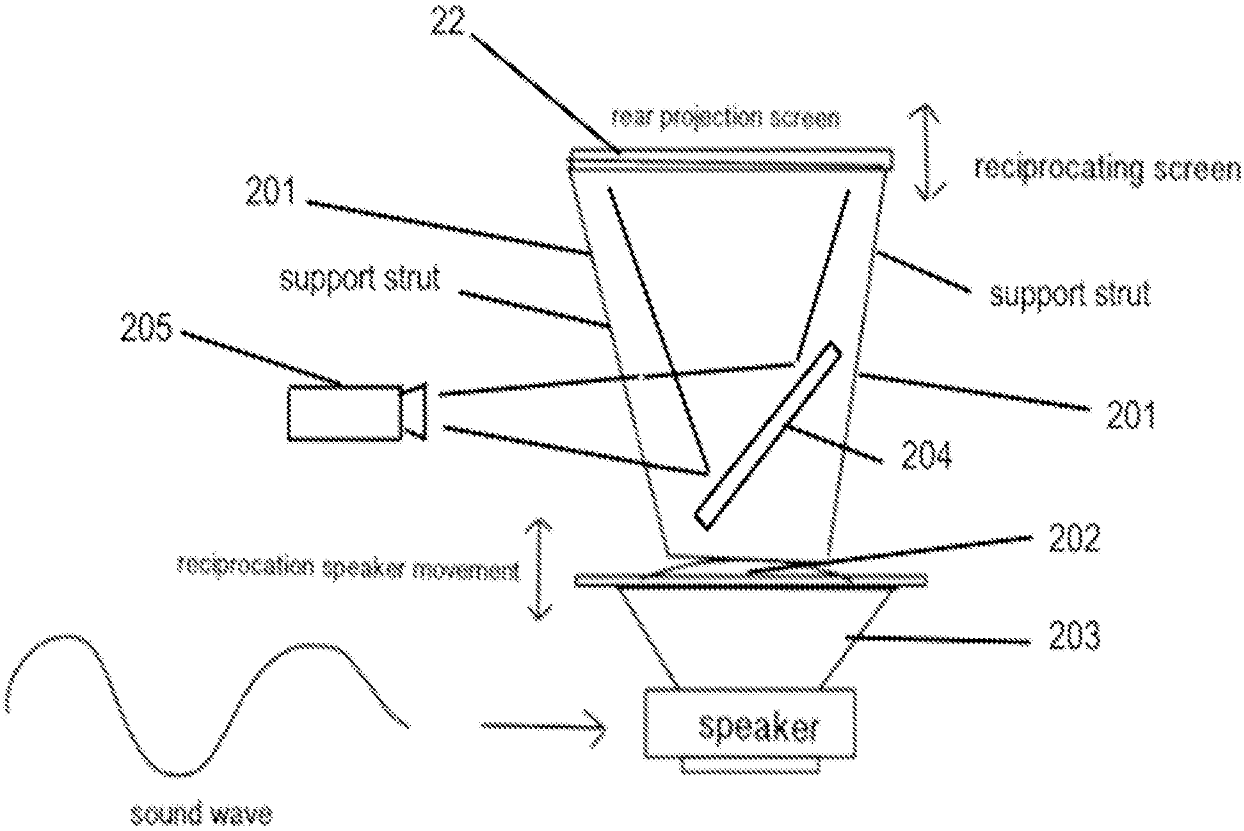

FIG. 2

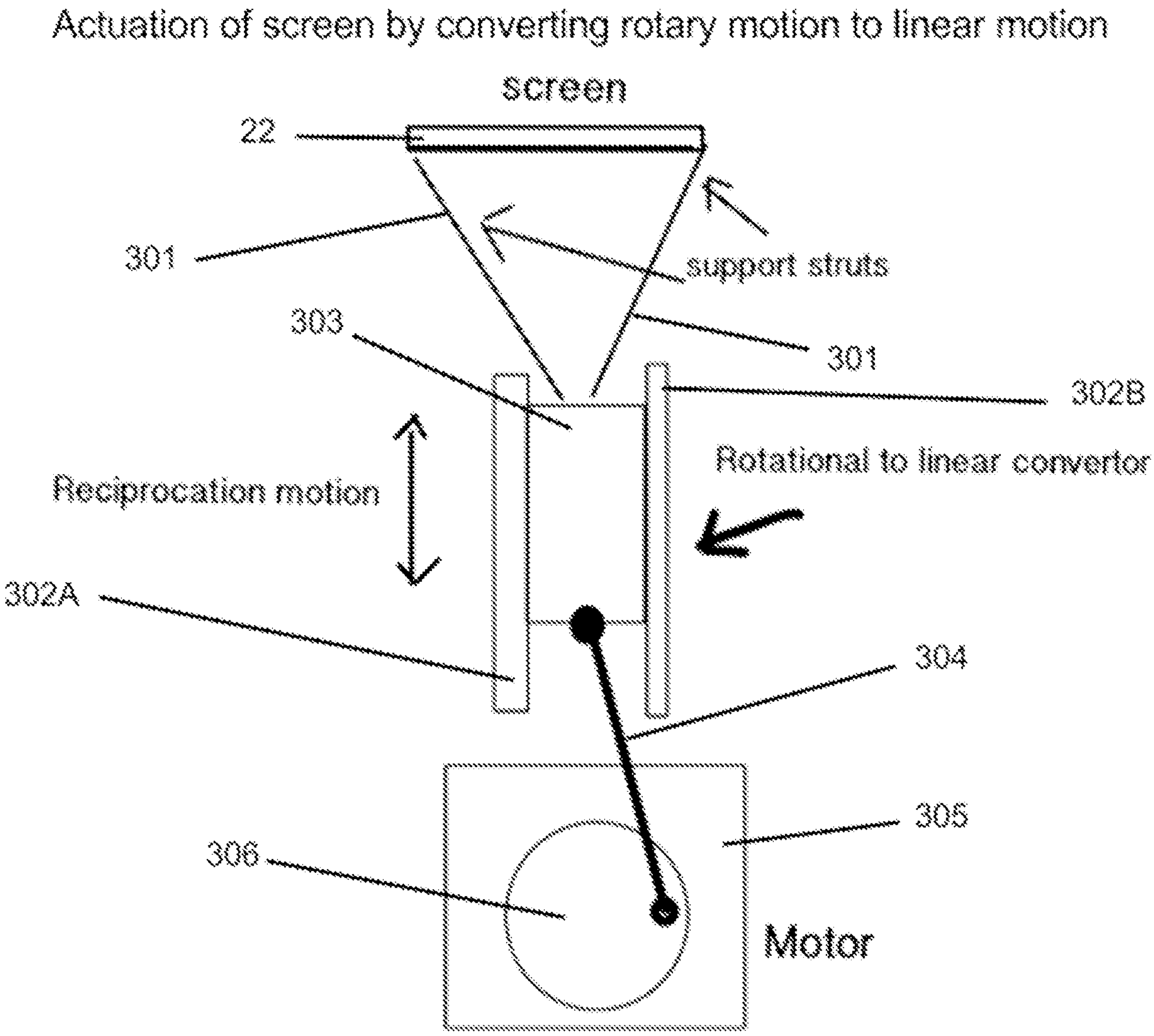
Actuation of screen by converting rotary motion to linear motion
screen
22
301
support struts
303
301
302B
Rotational to linear convertor
Reciprocation motion
302A
304
305
306
Motor

FIG. 3

Harmonic resonance and amplification of screen movement

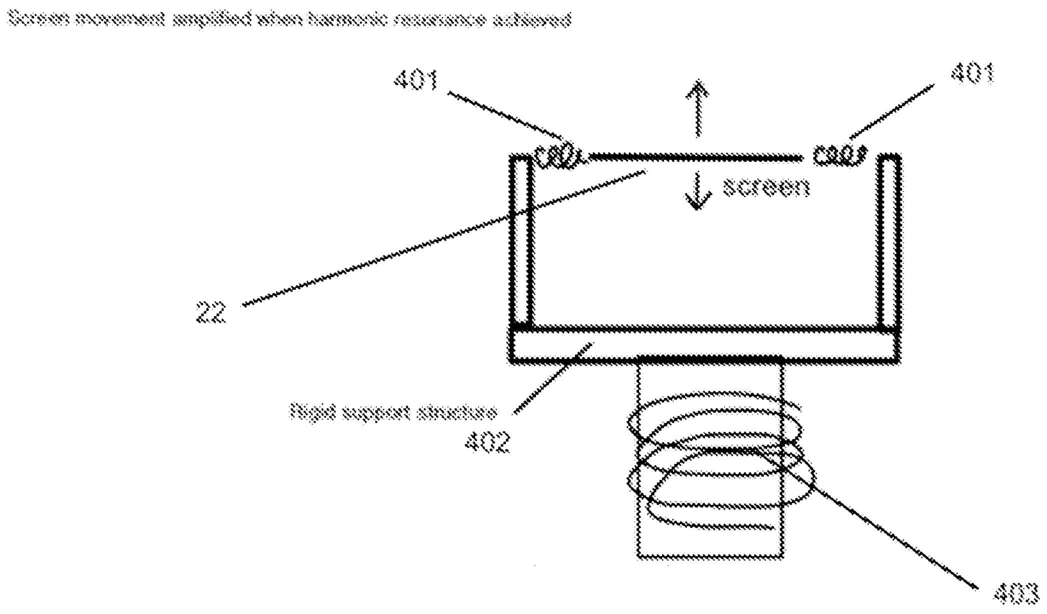

FIG. 4

Synchronization using an audio signal

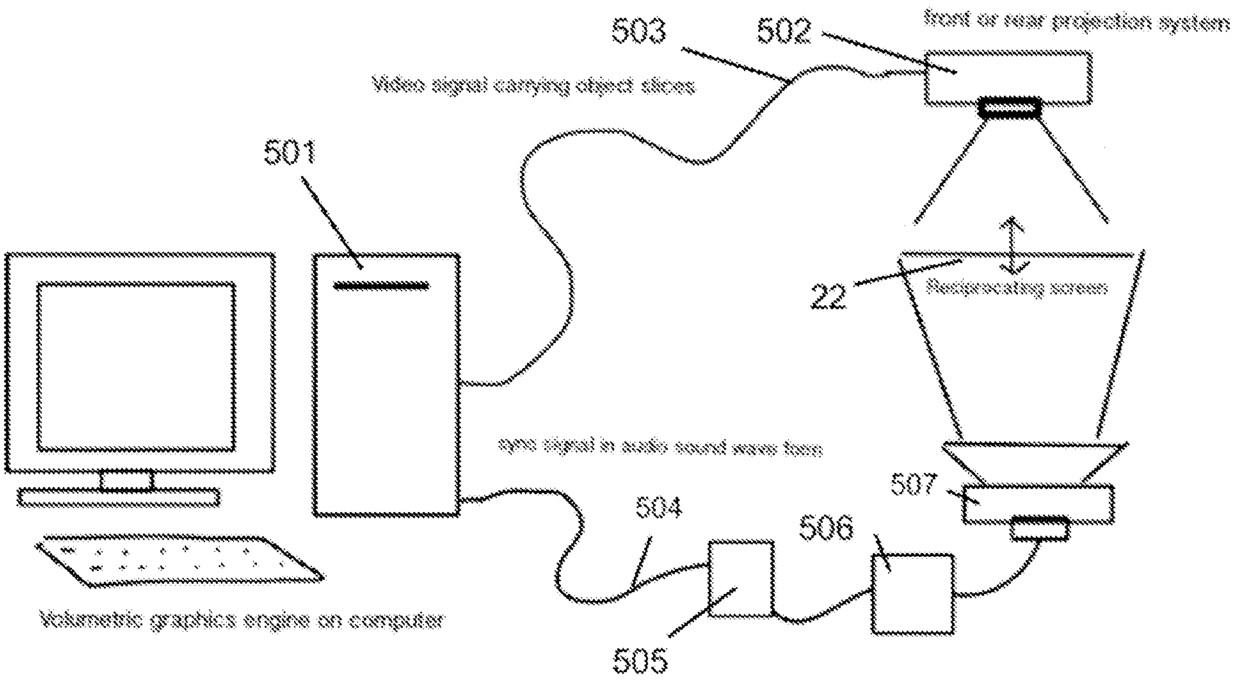

FIG. 5

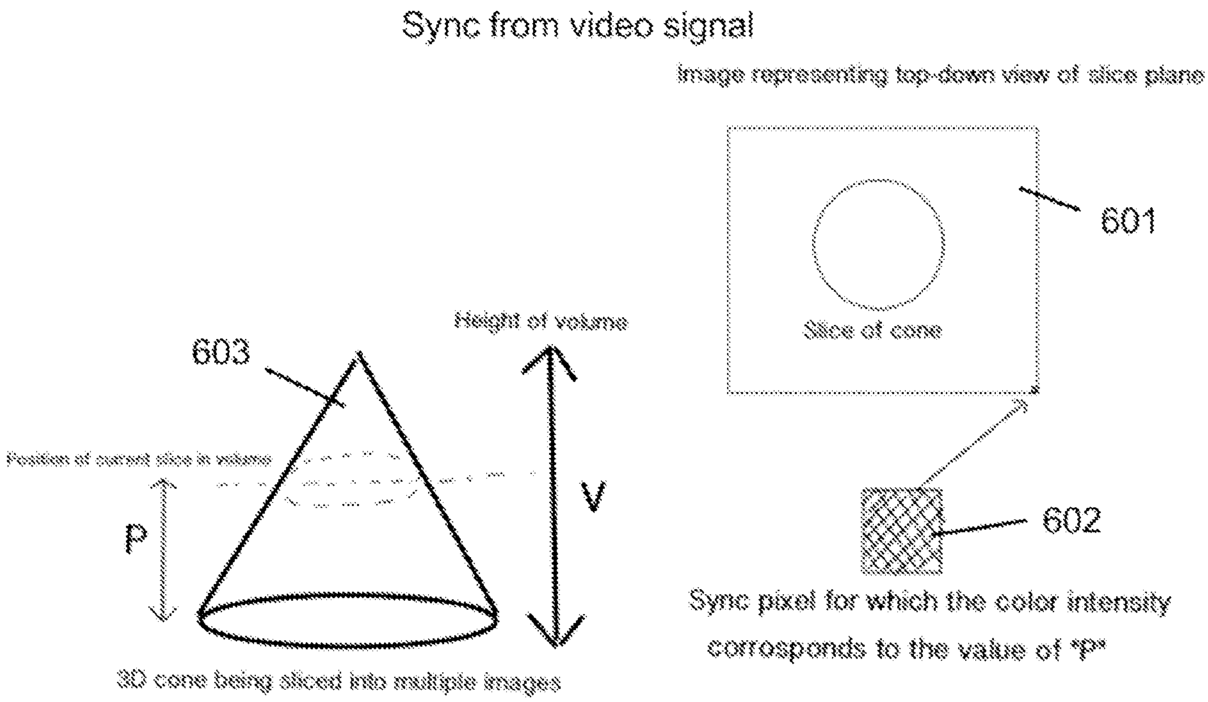
Sync from video signal
Image representing top-down view of slice plane
601
Slice of cone
Height of volume
603
Position of current slice in volume
V
P
602
Sync pixel for which the color intensity
corrosponds to the value of "P"
3D cone being sliced into multiple images

FIG. 6

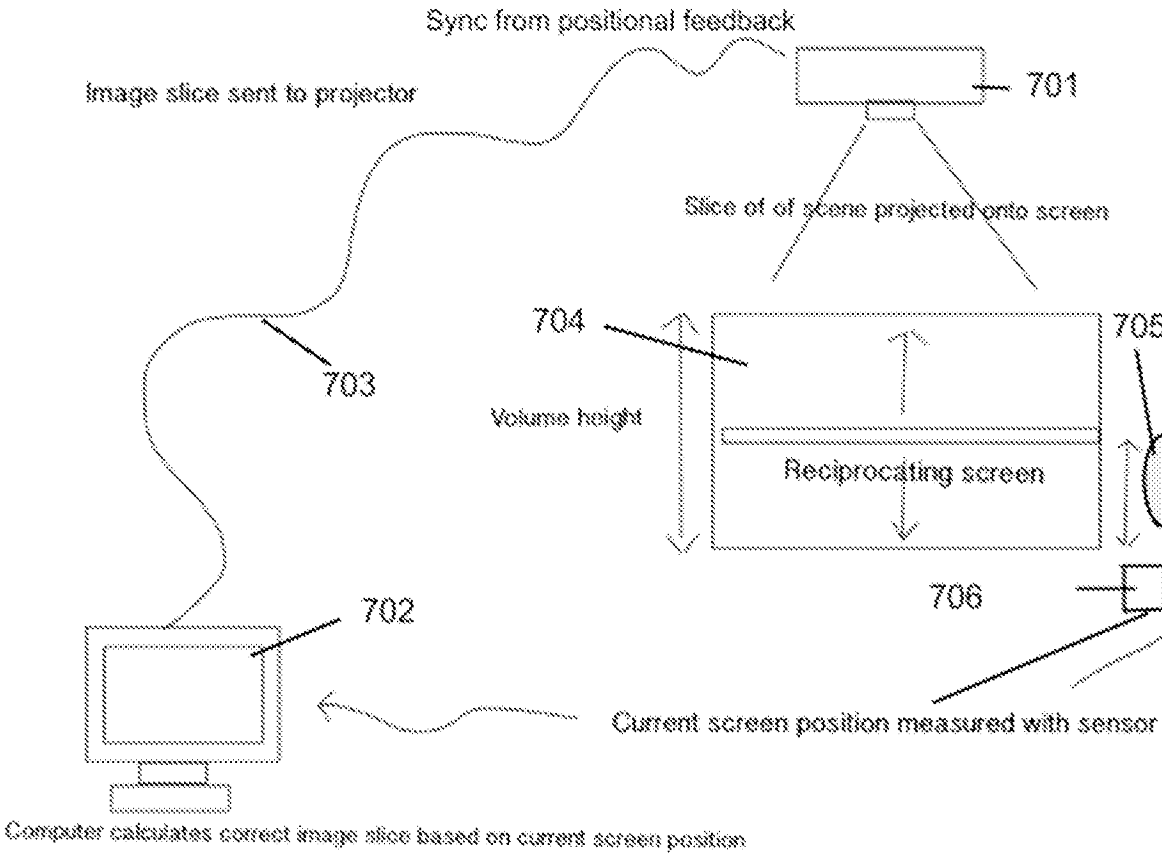
Sync from positional feedback
Image slice sent to projector
701
Slice of of scene projected onto screen
704
705
703
Volume height
Reciprocating screen
706
702
Current screen position measured with sensor
Computer calculates correct image slice based on current screen position

FIG. 7

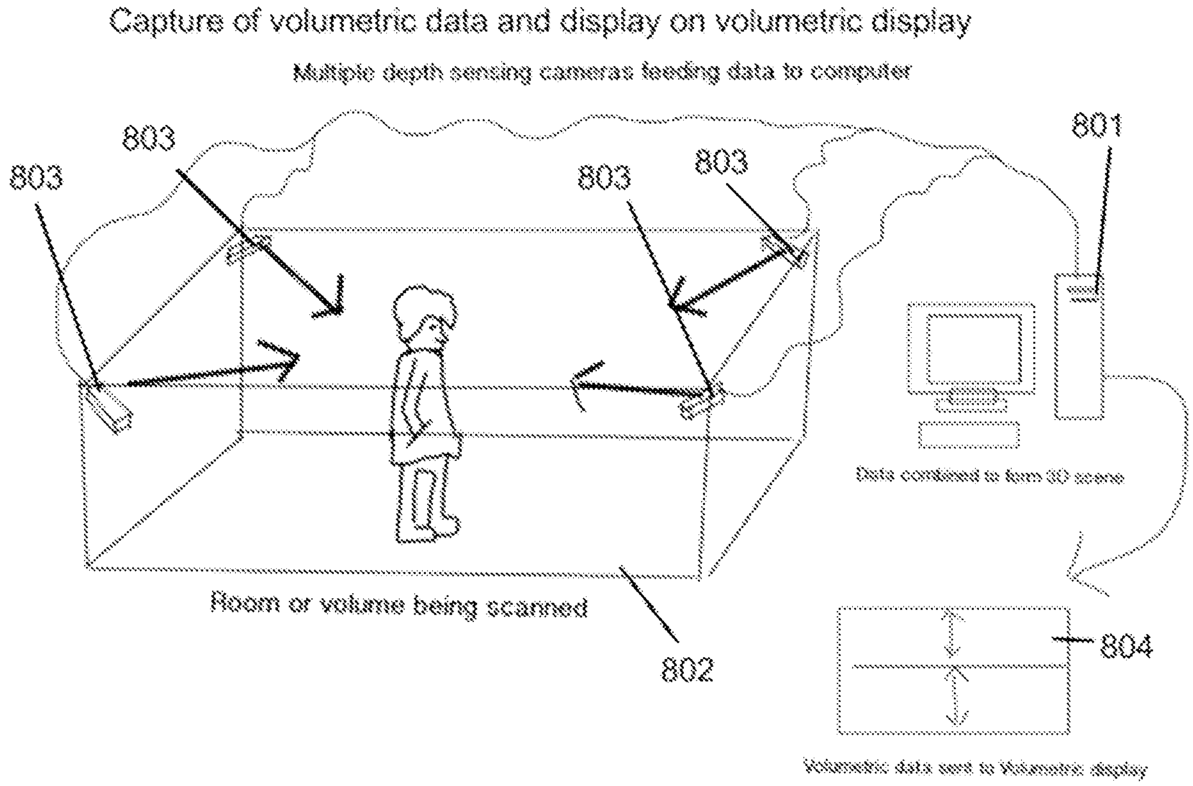
Capture of volumetric data and display on volumetric display
Multiple depth sensing cameras feeding data to computer
803
803
803
803
801
Data combined to form 3D scene
Room or volume being scanned
802
804
Volumetric data sent to Volumetric display

FIG. 8

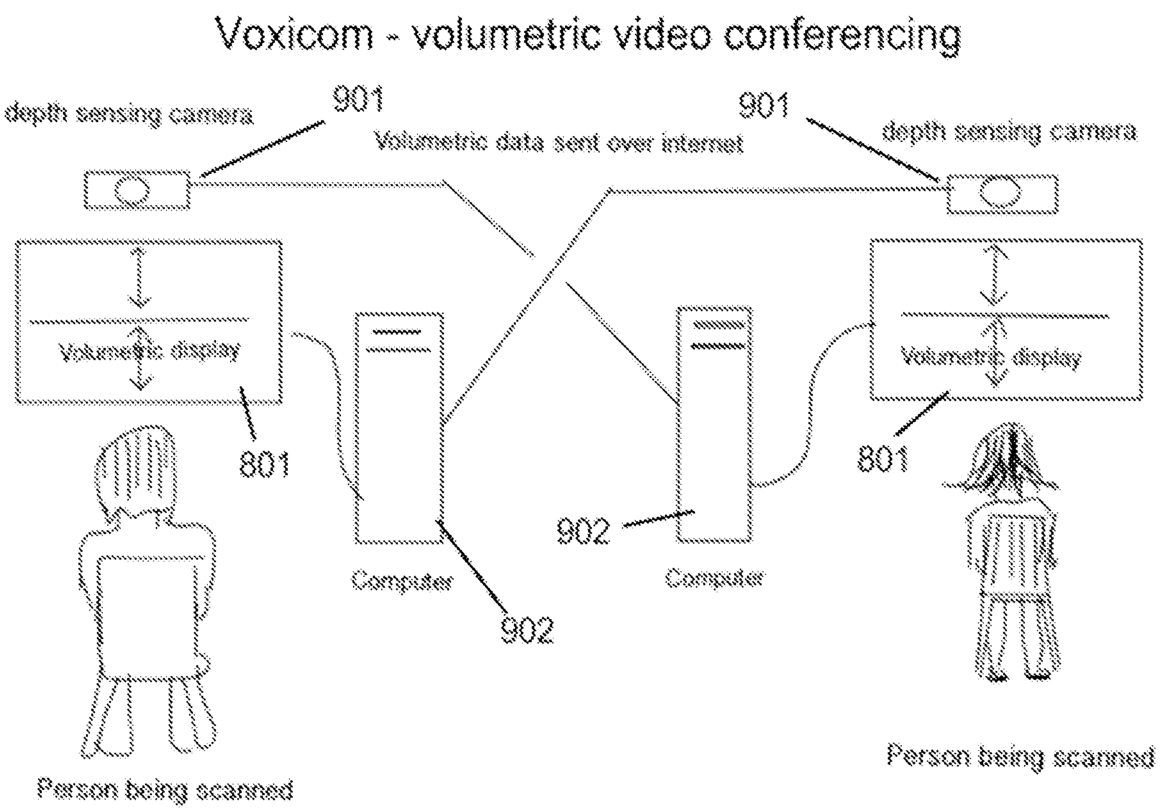
Voxicom - volumetric video conferencing
depth sensing camera
901
Volumetric data sent over internet
901
depth sensing camera
Volumetric display
Volumetric display
801
801
902
Computer
Computer
902
Person being scanned
Person being scanned

FIG. 9

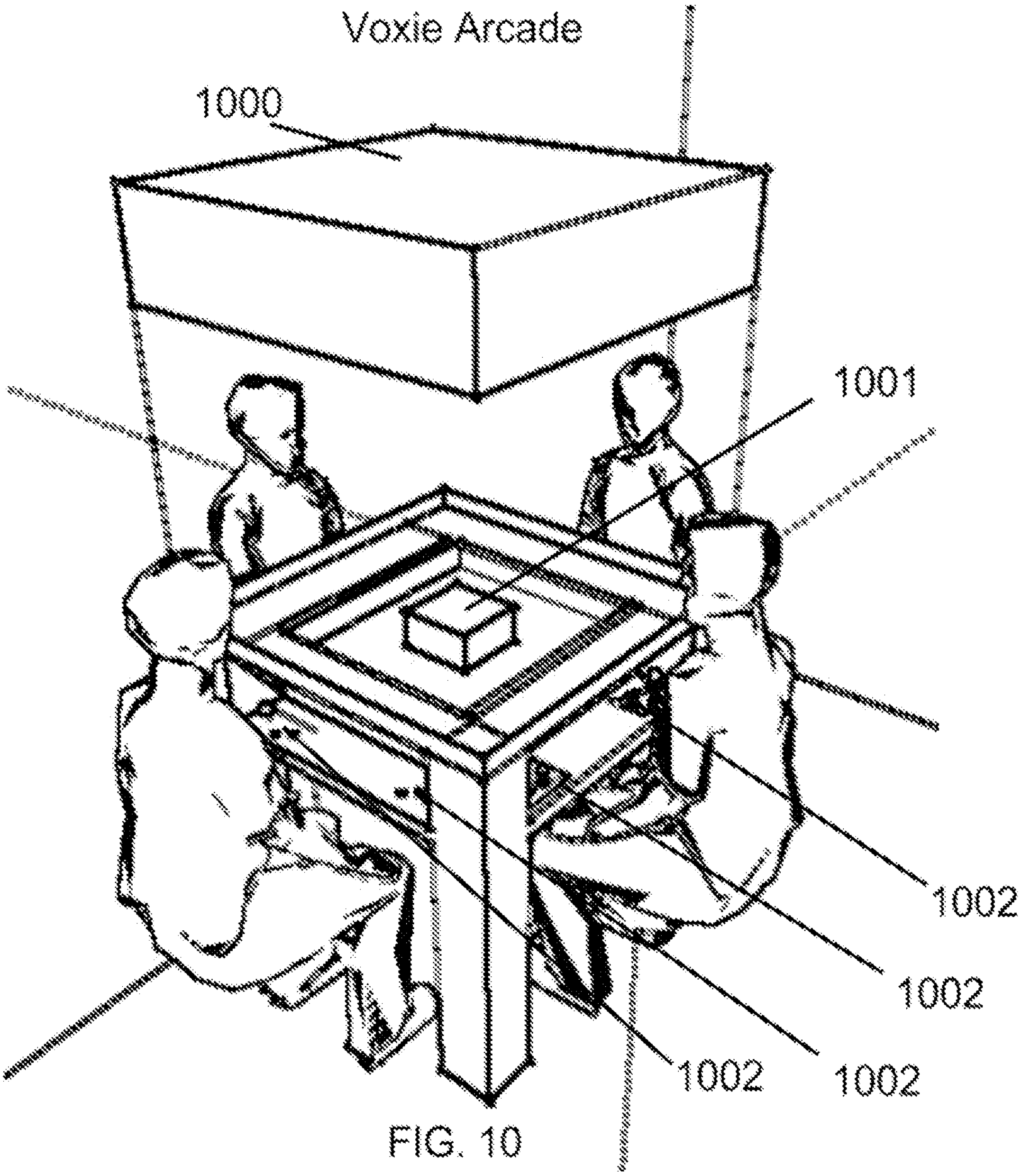

FIG. 10