(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 August 2014 (28.08.2014)

(10) International Publication Number
WO 2014/127841 A1

(51) International Patent Classification:
H04N 13/02 (2006.01) *H04N 7/18* (2006.01)
H04N 7/14 (2006.01)

(21) International Application Number:
PCT/EP2013/053704

(22) International Filing Date:
25 February 2013 (25.02.2013)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **TELEFONAKTIEBOLAGET L M ERICSSON (PUBL)** [SE/SE]; SE-164 83 Stockholm (SE).

(72) Inventors: **GIRDZIJAUSKAS, Ivana**; Armégatan 29, lgh 1604, S-17171 Solna (SE). **GRAFULLA-GONZALEZ, Beatriz**; Huvudstagatan 1D, S-17144 Solna (SE).

(74) Agent: **BARRETT, Peter**; Ericsson Limited, Unit 4 Midleton Gate, Guildford Business Park, Guildford Surrey GU2 8SG (GB).

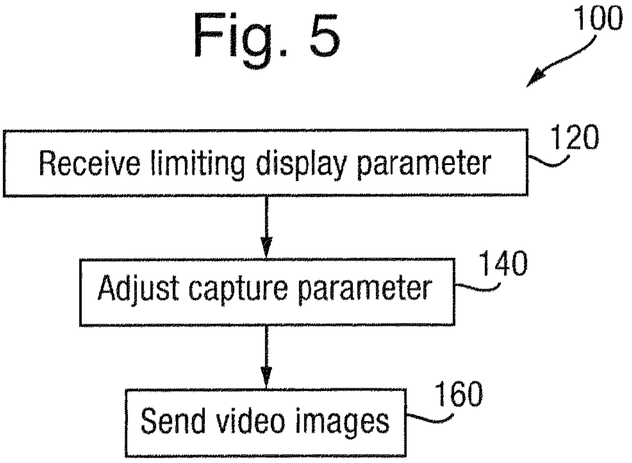
(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: 3D VIDEO APPARATUS AND METHOD

Fig. 5



(57) **Abstract**: A method for conducting in an apparatus configured to capture 3D video images for display on a 3D display device is disclosed. The method comprises the steps of receiving a limiting display parameter associated with the 3D display device, adjusting a capture parameter of the video apparatus according to the received limiting display parameter, and sending video images captured with the adjusted capture parameter to the 3D display device for display. Also disclosed are a computer program product for carrying out a method for such a method and a video apparatus configured to capture 3D video images for display on a 3D display device.

3D Video Apparatus and Method

Technical Field

The present invention relates to a video apparatus configured to capture 3D video images for display on a 3D display device, and to a system comprising video apparatus. The invention also relates to a method for conducting in a video apparatus and to a computer program product configured to implement a method in a video apparatus.

Background

Three dimensional video technology continues to grow in popularity, and 3D technology capabilities have evolved rapidly in recent years. A number of titles are produced for 3D cinema release each year and 3D enabled home cinema systems are widely available. 3D video conferencing systems are also available, with real time capture and display of 3D video content. Research in this sector continues to gain momentum, fuelled by the success of current 3D product offerings and supported by interest from industry, academia and consumers.

The term 3D is usually used to refer to a stereoscopic experience, in which an observer's eyes are provided with two slightly different images of a scene, which images are fused in the observer's brain to create an impression of depth. An anaglyph, shutter or polarized glasses are used to filter a display and present the different images to the left and right eyes of a viewer. This effect is typically used in 3D films for cinema release and provides an excellent 3D experience to a stationary observer. However, stereoscopic technology is merely one technique for producing 3D video images. A new generation of auto-stereoscopic displays allows the viewer to experience 3D video without glasses and to perceive 3D video from multiple viewing positions.

Auto-stereoscopic functionality is enabled by capturing a scene using many different cameras which observe the scene from different angles or viewpoints. These cameras generate what is known as multiview video. Suitable displays then project these different images in slightly different directions, as illustrated for example in Figure 1. A viewer located in a viewing position in front of the display will be presented with slightly different images of the same scene at each eye, which images will be fused in the viewer's brain to create the illusion of depth. Multiple views are projected and repeated at different viewing angles, allowing a viewer to change position in front of the display and still perceive a smooth 3D effect. The number of views generated for display typically varies between 7 and 28. In Figure 1, eight views are illustrated, each repeated at three different viewing angles. The shaded areas of the diagram illustrate areas where the 3D effect will not be perceived by the viewer, either because one eye does not receive a view, at the extremities of the viewing angle, or because the two views received by a viewer's eyes do not correspond to create a 3D effect, as is the case where repeated patterns of views meet.

Multiview video can be relatively efficiently encoded by exploiting both temporal and spatial similarities that exist in different views. However, even with multiview coding (MVC), the transmission cost for multiview video can remain prohibitively high. To address this, current auto-stereoscopic technologies only transmit a subset of the captured multiple views, typically between 2 and 3 key views selected from among the available views. To compensate for the missing information, depth and disparity maps are used to recreate the missing data. From the key video views transmitted and depth/disparity information, virtual views can be generated at any arbitrary viewing position, in a process known as view synthesis. Many techniques exist in the literature to achieve this, depth image-based rendering (DIBR) being one of the most prominent.

A depth map, as used in view synthesis, is simply a greyscale image of a scene in which each pixel indicates the distance between the corresponding pixel in a video object and the capturing camera. A disparity map is an intensity image conveying the apparent shift of a pixel which results from moving from one viewpoint to another. The link between depth and disparity can be appreciated by considering that the closer an object is to a capturing camera, the greater will be the apparent positional shift resulting from a change in viewpoint. A key advantage of depth and disparity maps is that they contain large smooth surfaces of constant grey levels, making them comparatively easy to compress for transmission using current video coding technology.

In both stereoscopic and multiview video technologies, the 3D experience of the viewer is highly dependent upon the physical set up at both the capture side, where the 3D video is recorded, and the display side, where the 3D video is displayed. At the capture side, scene and camera parameters are carefully chosen to provide the best user experience. These parameters are known as capture parameters, and may for example include camera baseline distance, focal length, distance to the scene to be recorded etc. At the display side, the appearance of the transmitted 3D video content is dependent not only upon the capture parameters but also on what are known as display parameters, including viewing distance, screen width and display parallax.

In many situations, the capture and display parameters for a segment of 3D video may be adjusted independently, which can lead to a mismatch between the setup at the capture and display sides. Such a mismatch can lead to parts of a scene being perceived too close to a viewer or too far away, such that the eyes diverge when attempting to observe them. Such extremes of distance render the 3D images difficult for a viewer to process, resulting in an unpleasant viewing experience and causing eye strain and fatigue, particularly if displayed over a long period of time.

International Patent Application PCT/EP2011/069942 discloses a video apparatus and method in which rendering parameters for depth image based rendering are adjusted at the display side according to at least one parameter of a display on which 3D video content is to be shown. In this manner, a view may be synthesized which corresponds to the particular display in question while maintaining the relative depth perception, thus ensuring a good 3D experience for a viewer.

International Patent Application number PCT/EP2012/071397 discloses a 3D warning system for quality monitoring in a situation in which 3D video content may be captured and displayed in real time. The system monitors capture and display parameters and signals an issue if a mismatch between the capture and display parameters is identified.

Summary

It is an aim of the present invention to provide a method, apparatus, system and computer program product which obviate or reduce at least one or more of the disadvantages discussed above.

According to an aspect of the present invention, there is provided a method for conducting in an apparatus configured to capture 3D video images for display on a 3D display device. The method comprises receiving a limiting display parameter associated with the 3D display device and adjusting a capture parameter of the video apparatus according to the received limiting display parameter. The method further comprises sending video images captured with the adjusted capture parameter to the 3D display device for display.

Embodiments of the present invention thus ensure a good 3D experience for a viewer by sending a limiting display parameter associated with a destination display device to a capture apparatus, and adjusting at least one capture parameter according to the received limiting display parameter. In this manner, it may be ensured that 3D video is captured in such a manner that it will be suitable for display on the destination 3D display device, thus ensuring good depth perception and a comfortable viewing experience.

In some examples, the limiting display parameter may comprise at least one of a maximum and/or minimum display parallax.

In some examples, receiving a limiting display parameter may comprise receiving a message including the limiting display parameter. Examples of a received message may include a Session Description Protocol (SDP) message or a Realtime Transport Control Protocol (RTCP) message or an H.323 message.

In some examples, the capture parameter may comprise one of focal length, baseline separation or sensor shift.

In further examples, the apparatus may be associated with a 3D display device and may be configured to receive 3D images for display from a second video apparatus. In such examples, the method may further comprise sending a limiting parameter of the associated 3D display device to the second video apparatus. Accordingly, a single video apparatus may conduct both capture and receive operations, adjusting a capture parameter according to a limiting display parameter received from a destination display device.

In some examples, the method may further comprise checking whether or not 3D video captured with the existing capture parameters is in accordance with the received limiting display parameter.

In other examples, the method may further comprise checking, after adjustment of the capture parameter, whether or not 3D video captured with the adjusted capture parameter is in accordance with the received limiting display parameter. If the 3D video captured with the adjusted capture parameter is not in accordance with the received limiting display parameter, the method may comprise adjusting at least one other capture parameter of the video apparatus. If the 3D video captured with the adjusted capture parameters is still not in accordance with the received limiting display parameter, the method may comprise sending 2D video content to the display device.

In some examples, the method may further comprise receiving a limiting display parameter associated with at least one other 3D display device and sending video images captured with the adjusted capture parameter to the other 3D display device for display. In such examples, adjusting a capture parameter of the video apparatus may comprise identifying which of the received limiting display parameters represents a greater constraint on capture parameters, and adjusting the capture parameter according to the identified limiting display parameter. In this manner, the method may accommodate the display of captured 3D video content on multiple display devices, the video apparatus receiving limiting display parameters from each of the display devices to which video is to be sent. The apparatus identifies the most limiting of the received parameters and adjusts the capture parameter according to this most limiting case. In this manner, it may be assured that the captured video is suitable for display on all of the display devices to which the video is to be sent.

According to some examples, adjusting a capture parameter may comprise calculating an adjustment factor range for the capture parameter, wherein the calculation is based upon the received limiting display parameter and the capture parameter. Adjusting may further comprise selecting an adjustment factor from the calculated range and applying the selected adjustment factor to the capture parameter.

In some examples, the adjustment factor range may comprise values of an adjustment factor resulting in a display parameter in accordance with the received limiting display parameter.

In some examples, the method may further comprise receiving a screen dimension of the 3D display device, and the calculation of an adjustment factor range may also be based upon the received screen dimension.

In some examples, applying the selected adjustment factor may comprise changing a physical capture arrangement such that the capture parameter is multiplied by the selected adjustment factor. This may for example comprise changing the baseline, focal length or sensor shift of the capture arrangement such that the baseline, focal length or sensor shift are multiplied by the selected adjustment factor.

In other examples, applying the selected adjustment factor may comprise selecting a view from an existing multiview set in which the capture parameter is multiplied by the selected adjustment factor. In still further examples, if for example an existing view in which the capture parameter is multiplied by the selected adjustment factor is not available, applying the selected adjustment factor may comprise synthesizing a view in which the capture parameter is multiplied by the selected adjustment factor.

According some examples, the calculation of an adjustment factor range may also be based upon at least one other capture parameter. The at least one other capture parameter may comprise one or more of maximum depth, minimum depth, maximum disparity, minimum disparity, sensor shift, focal length, baseline separation and/or sensor width.

According to some examples, the method may further comprise checking that the selected adjustment factor is within an acceptable apparatus limit. If the selected adjustment factor is not within an acceptable apparatus limit, the method may further comprise selecting an adjustment factor within an acceptable apparatus limit that is closest to the calculated range, applying the selected adjustment factor to the capture parameter and conducting the steps of calculating an adjustment factor range, selecting an adjustment factor from the calculated range, and applying the selected adjustment factor for at least one other capture parameter of the video apparatus. The calculation of the adjustment factor range for the at least one other capture parameters may be based upon the received limiting display parameter, the adjusted capture parameter and the at least one other capture parameter. In this manner, examples of the present invention may account for situations in which a calculated adjustment factor range indicates a parameter change of a magnitude that is undesirable or unsupported by the capture apparatus. In such situations, a second capture parameter may also be adjusted in order to arrive at a capture situation that is compatible with the limiting display parameter or parameters of a destination display apparatus.

According to another aspect of the present invention, there is provided a computer program product which, when run on a computer, causes the computer to carry out a method according to the first aspect of the present invention.

According to another aspect of the present invention, there is provided a video apparatus configured to capture 3D video images for display on a 3D display device. Examples of the apparatus may comprise a receiving unit configured to receive a limiting display parameter associated with the 3D display device, an adjusting unit configured to adjust a capture parameter of the video apparatus according to the received limiting display parameter, and a sending unit configured to send video images captured with the magnified capture parameter to the 3D display device for display.

In some examples, the limiting display parameter may comprise at least one of a maximum and/or minimum display parallax.

In some examples, the receiving unit may be configured to receive a message including the limiting display parameter. Examples of such received messages may include a Session Description Protocol (SDP) message or a Realtime Transport Control Protocol (RTCP) message or an H.323 message.

In some examples, the capture parameter may comprise at least one of focal length, baseline separation and/or sensor shift.

In some examples, the apparatus may be associated with a 3D display device and may be configured to receive 3D images for display from a second video apparatus. In such examples, the sending unit may be configured to send a limiting parameter of the associated 3D display device to the second video apparatus.

In some examples, the apparatus may further comprise a first checking unit configured to check whether or not 3D video captured with the existing capture parameters is in accordance with a limiting display parameter received by the receiving unit.

In further examples, the first checking unit may also be configured to check, after adjustment of the capture parameter by the adjusting unit, whether or not 3D video captured with the adjusted capture parameter is in accordance with a limiting display parameter received by the receiving unit.

In some examples, the receiving unit may be further configured to receiving a limiting display parameter associated with at least one other 3D display device; and the sending unit may be further configured to send video images captured with the adjusted capture parameter to the other 3D display device for display. The receiving unit may further comprise an identification unit configured to identify which of the limiting display parameters received by the receiving unit represents a greater constraint on capture parameters.

In some examples, the adjusting unit may comprise a calculating unit configured to calculate an adjustment factor range for the capture parameter of the video apparatus, wherein the calculation is based upon the received limiting display parameter and the capture parameter. The adjusting unit may further comprise a selecting unit configured to select an adjustment factor from the calculated range and an application unit configured to apply the selected adjustment factor to the capture parameter.

In some examples, the adjustment factor range may comprise values of an adjustment factor resulting in a display parameter in accordance with the received limiting display parameter.

According to some examples, the receiving unit may be further configured to receive a display screen dimension, and the calculation unit may be further configured to base the calculation of magnification factor range upon the received display screen dimension.

According to some examples, the application unit may be configured to change a physical capture arrangement such that the capture parameter is multiplied by the selected adjustment factor.

In other examples, the application unit may be configured to select a view from an existing multiview set in which the capture parameter is multiplied by the selected adjustment factor. In still further examples, if for example an existing view in which the capture parameter is multiplied by the selected adjustment factor is not available, the application unit may be configured to synthesize a view in which the capture parameter is multiplied by the selected adjustment factor.

In some examples, the calculating unit may be further configured to base the calculation of the adjustment factor range upon at least one other capture parameter. The at least one other capture parameter may comprise one or more of: maximum depth, minimum depth, maximum disparity, minimum disparity, sensor shift, focal length, baseline separation and/or sensor width.

According to some examples, the adjustment unit may further comprise a second checking unit configured to check that the selected adjustment factor is within an acceptable apparatus limit. The second checking unit may further be configured such that, if the selected adjustment factor is not within an acceptable apparatus limit, the second checking unit instructs the selecting unit to select an adjustment factor within an acceptable apparatus limit that is closest to the calculated range; and instructs the calculating, selecting and application units to calculate an adjustment factor range, select an adjustment factor from the calculated range, and apply the selected adjustment factor for at least one other capture parameter of the video apparatus. The calculating unit may be configured to base the calculation upon the received limiting display parameter, the adjusted capture parameter and the at least one other capture parameter.

According to another aspect of the present invention, there is provided a system for 3D video capture and display, the system comprising a first video apparatus configured to capture 3D video images and a second video apparatus associated with a 3D display device configured to display 3D video images. The second video apparatus may be configured to receive 3D images for display from the first video apparatus and to send a limiting display parameter of the 3D display device to the first video apparatus. The first video apparatus may be configured to receive the limiting display parameter from the second video apparatus, adjust a capture parameter of the first video apparatus, and send video images captured with the adjusted capture parameter to the second video apparatus for display.

Features disclosed in connection with one aspect, embodiment or example of the present invention may be combined or incorporated in another aspect, embodiment or example of the present invention.

Brief description of the drawings

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the following drawings in which:

Figure 1 illustrates a multiview display scheme;

Figure 2 illustrates a stereoscopic camera setup;

Figure 3 illustrates positive, zero and negative parallax;

Figure 4 illustrates a stereoscopic display setup;

Figure 5 is a flow chart illustrating steps in a method for a video apparatus;

Figure 6 is a block diagram illustrating functional elements of a video apparatus;

Figure 7 is a flow chart illustrating steps in another example of method for a video apparatus;

Figure 8 illustrates a change in focal length for a stereoscopic camera setup;

Figure 9 illustrates a change in baseline separation for a stereoscopic camera setup;

Figure 10 illustrates a change in sensor shift for a stereoscopic camera setup;

Figure 11 is a flow chart illustrating steps in another example of method for a video apparatus.

Figure 12 is a block diagram illustrating functional elements of another example of a video apparatus; and

Figure 13 is a schematic representation of a system comprising first and second video apparatus.

Detailed Description

The present invention provides a method, computer program product and apparatus that enable adjustment of 3D capture parameters according to limiting display parameters at a device or devices on which the captured 3D video content is to be displayed. A video apparatus configured to capture 3D video images receives from a destination display device a limiting display parameter of that display device. The video apparatus then adjusts a capture parameter of the video apparatus according to the received limiting display parameter and sends video images captured with the adjusted capture parameter to the 3D display device for display. The method, computer program product and apparatus of the present invention thus allow for real time adjustment of 3D video capture parameters so as to avoid a conflict between capture and display parameters, and so improve the 3D viewing experience of an observer watching the captured 3D video content. The invention may be applied for example in 3D video conferencing systems, where real time capture and display of 3D video content is required.

In order to provide context for the following disclosure, a brief discussion of 3D camera and display geometry is given below. For the purposes of explanation, the following discussion, as well as many of the embodiments described below, is illustrated with respect to a stereo camera setup. However, it will be appreciated that similar principles may be applied to setups involving multiple cameras and depth plus image cameras.

Figure 2 illustrates a common arrangement for a stereo camera 10. According to this arrangement, known as a parallel sensor-shifted setup, convergence of the two cameras 10a, 10b is established by a small shift of magnitude $h/2$ of each of the camera sensor targets. This setup has been found to provide better stereoscopic quality than the often used toed-in setup, in which the two cameras are inward-rotated until the convergence is established.

Each of the cameras 10a, 10b has a focal length f and the distance between the optical centres of the two cameras, known as the baseline, baseline distance or baseline separation, is t_c. The distance from the camera optical centres to the convergence plane 12, known as the convergence distance, is Z_C. A point 14 on a captured object is at a distance or depth Z from the cameras. Each camera 10a, 10b captures an image of the same scene containing objects at varying depth Z. Points on each captured image will appear in different places on the two captured images, owing to the different arrangements of the cameras 10a, 10b. The distance between point 16a in the left image and point 16b in the right image, each corresponding to the same point 14 on a captured object, is called the disparity *d*.

The above discussed parameters are referred to collectively as capture parameters, and are mathematically related. The following expression may be derived relating these capture parameters:

$$d = h - \frac{t_c f}{Z} = t_c f(\frac{1}{Z_C} - \frac{1}{Z}) \qquad \text{Equation (1)}$$

As can be seen from Figure 2, points on objects captured at the convergence plane, that is at a depth of $Z=Z_C$, have zero disparity, appearing at exactly the same position on the left and right images. This property allows the derivation of the following expression:

$$h = \frac{t_c f}{Z_c} \qquad \text{Equation (2)}$$

Points on objects captured at depths less than that of the convergence plane, $Z<Z_C$ can be seen to have negative values of disparity, while points captured at depths $Z>Z_C$ can be seen to have positive values of positive disparity.

As discussed above, stereoscopic 3D displays create the impression of depth by showing simultaneously the two slightly different images captured by the left and right cameras 10a, 10b to the left and the right eyes of a viewer. Both images are presented on a display screen and a mechanism is used to display a different image to each eye of a viewer. This mechanism may for example include polarization filters on the screen and corresponding glasses for the viewer. An important parameter that controls the perception of depth experienced by the viewer in watching these images is the so-called screen parallax *P*, which represents the spatial distance between corresponding points in the left and the right view as they appear on a display screen. The depth perception experienced by the viewer with respect to each point on the captured scene is dependent upon many parameters but the key factors are the type and amount of parallax.

Different types of parallax are illustrated in Figure 3. Figure 3a illustrates positive parallax, according to which a point in the right-eye view appears on the screen to the right of the corresponding point in the left-eye view. Positive parallax gives an impression of an object 14 that is at a depth greater than that of the screen 20, in so-called screen space. Figure 3b illustrates zero parallax, according to which a point in the right-eye view appears on the screen at exactly the same position as the corresponding point in the left-eye view. Objects 14 having zero parallax appear to the viewer to be at the same depth as the screen. Figure 3c illustrates negative parallax, according to which a point in the right-eye view appears on the screen to the left of the corresponding point in the left-eye view. Negative parallax gives an impression of an object that is at a depth less than that of the screen, in so-called viewer space.

It will be appreciated that object disparity d on the capture side, and object parallax P on the display side are analogous, and may be linked by the following expression:

$$S_M = \frac{P}{d} = \frac{W_D}{W_S} \qquad \text{Equation (3)}$$

Where W_D is the display or screen width on the display side and W_S is the sensor width on the capture side. S_M is defined as the magnification factor linking capture and display geometries.

Figure 4 illustrates a common arrangement for 3D stereo display. The arrangement comprises a screen 20 which simultaneously displays left and right images and includes a mechanism for presenting a different image to each eye 22a, 22b of a viewer. As discussed above, the separation of image points on the left and right image representing the same point on a captured object is the parallax P. The distance between the viewer's eyes is known as the inter-ocular distance and represented as t_e and the viewer is considered to be positioned at a viewing distance Z_D from the screen. The ideal viewing distance may vary according to screen size. For example, in the case of High Definition (HD) resolutions, the best viewing distance is usually considered to be 3 times the screen height. This constant factor may however be different for different screen resolutions and may also vary according to display technology.

The following expression may be derived for the perceived depth Z_p of an object point:

$$Z_p = \frac{Z_D \cdot t_e}{t_e - P} \qquad \text{Equation (4)}$$

The effects of positive, negative and zero parallax can be appreciated from the above equation; objects with a positive parallax being perceived to be in the screen space (Z_p>Z_D), objects with zero parallax appearing on the screen surface (Z_p=Z_D), and objects with negative parallax appearing in viewer space (Z_p<Z_D).

A 3D display is characterized by a parallax range [P_{min}, P_{max}] over which 3D viewing is comfortable. The maximum value of parallax that human eyes can process without diverging is equal to the inter-ocular distance, i.e., $P_{max}=t_e$. However, the inter-ocular distance represents a limiting case which often does not equate to comfortable viewing in real stereo setups, where the furthest objects are typically placed at some lesser distance comfortable for viewers. The minimum value of parallax for a display may be approximated by the expression: $P_{min}=t_e - Z_D \cdot \Delta\alpha_{total}$, where $\Delta\alpha_{total}$ is the total convergence angle. The total convergence angle is itself the sum of the two vergence ranges, one for the viewer space in front of the display and one for the screen space behind the display. An established rule of thumb is to set $\Delta\alpha_{total}$ to 0.02 *rad*. Although this figure is conservative based on current knowledge, it offers a safe estimate. Different display apparatus may have other recommended values for P_{min}. Screen parallax values that are outside the recommended parallax range can be tolerated for short periods of time, but they are not recommended for extended viewings as they lead to discomfort and fatigue for the viewer.

Figure 5 illustrates steps in a method 100 for conducting in an apparatus configured to capture 3D video images for display on a 3D display device in accordance with an embodiment of the present invention. In a first step 120 of the method, the apparatus receives a limiting display parameter associated with the 3D display device. The limiting display parameter may for example be a maximum and/or minimum display parallax of the 3D display device. The apparatus then proceeds at step 140 to adjust a capture parameter of the video apparatus according to the received limiting display parameter. The capture parameter may for example comprise one or more of camera focal length, baseline distance and/or sensor shift. According to some examples, adjusting a capture parameter according to the receiving limiting display parameter may comprise calculating an adjustment factor range for the capture parameter and selecting an adjustment factor from the calculated range. This process is discussed in further detail with reference to Figures 7 to 10 and 11 below. Finally, at step 160, the apparatus sends video images captured with the adjusted capture parameter to the 3D display device for display.

The method 100 may be carried out on a video apparatus 200, functional units of which are illustrated in Figure 6. The apparatus 200 may execute steps of the method 100 for example according to computer readable instructions received from a computer program. The apparatus 200 comprises a receiving unit 220, configured to receive a limiting display parameter associated with a display device, an adjusting unit 240, configured to adjust a capture parameter of the video apparatus according to the received limiting display parameter, and a sending unit 260, configured to send video images captured with the adjusted capture parameter to the 3D display device for display. It will be understood that the units of the apparatus are functional units, and may be realised in any appropriate combination of hardware and/or software.

Figure 7 illustrates steps in another method 300 for conducting in an apparatus configured to capture 3D video images for display on a 3D display device in accordance with an embodiment of the present invention. The method 300 illustrates one example of how the steps of the method 100 may be further subdivided in order to realise the functionality discussed above. The method 300 also comprises additional steps which may be conducted in accordance with embodiments of the present invention.

In a first step 320 of the method 300, the apparatus receives limiting display parameters maximum parallax P_{max} and minimum parallax P_{min} associated with the 3D display device. The apparatus also receives the display width W_D of the 3D display device. The apparatus then proceeds, at step 328 to calculate an adjustment factor range for a capture parameter of the apparatus. At step 330 the apparatus selects an adjustment factor from the calculated range and at step 340a the apparatus applies the selected adjustment factor to the capture parameter. Finally, at step 360, the apparatus sends images captured with the adjusted capture parameter to the 3D display device.

As discussed above, the capture parameter to be adjusted may comprise one or more of a camera focal length, baseline distance between cameras and/or camera sensor shift. Calculation of adjustment factor ranges for each of these parameters is discussed below with reference to Figures 8, 9 and 10.

Figure 8 illustrates the effect that may be achieved by adjusting camera focal length at the capture side. Adjusting camera focal length (i.e. the zoom of the camera) is one way in which depth perception in the captured video images may be adjusted, so rendering the images more comfortable for viewing on a particular display device. Figure 8 illustrates two cameras 10a, 10b of a stereo camera setup. In the first illustrated arrangement of Figure 8, the cameras 10a, 10b have a focal length f_1, giving rise to a convergence plane at depth Z_{C1}. In the second illustrated arrangement, the focal length of the cameras 10a, 10b has been adjusted to $f_2 = \alpha f_1$, where α is an adjustment factor for the focal length and the sensor shift h and baseline distance t_c remain unchanged. The changed focal lengths give rise to a convergence place at a second depth Z_{C2}. In the arrangements illustrated in Figure 8, the adjustment factor α is positive, leading to a convergence plane post adjustment that is at a greater depth than the initial convergence plane.

Simple geometry can be used to prove that $Z_{c2}=\alpha Z_{c1}$. The following expressions can also be derived from the above relation and the equations developed above relating capture and display geometry for a stereo 3D setup:

$$\frac{P_2}{P_1} = \frac{Z - \alpha Z_{c1}}{Z - Z_{c1}} \qquad \text{Equation (5)}$$

and:

$$P_2 - P_1 = \frac{S_M t_c f_1}{Z}(1-\alpha) \qquad \text{Equation (6)}$$

From equation (6), it can be shown that $P_2 \leq P_1$ for $\alpha \geq 1$. Thus by increasing the focal length (positive values of the adjustment factor α causing the cameras to zoom in on the captured scene) the parallax of the captured images may be reduced. Three distinct cases may be identified for positive values of the adjustment factor α, distinguished by the position of a captured object relative to the initial and post adjustment convergence planes.

Objects that appeared in viewer space before the adjustment: $Z< Z_{C1}$ had negative initial values of Parallax P_1. For these objects, the parallax post adjustment P_2 is more strongly negative, indicating that these objects appear even closer to the viewer following the adjustment: $P_2 \leq P_1 \leq 0$.

Some objects that appeared in screen space before the adjustment appear in viewer space following adjustment. This change in the type of parallax applies to objects at a depth falling between the initial and post adjustment convergence planes, that is objects at depths Z satisfying the expression: $Z_{C1} \leq Z < \alpha Z_{C1}$. These objects change from having positive values of parallax P_1 before the adjustment to negative values of parallax P_2 post adjustment: $P_2 < 0 \leq P_1$.

Finally, distant objects in screen space before the adjustment remain in screen space after the adjustment but appear closer to the viewer. That is objects having a depth Z greater than the post adjustment convergence plane: $Z \geq \alpha Z_{C1}$, have post adjustment parallax vales P_2 that remain positive but are reduced compared to the pre adjustment values P_1: $0 \leq P_2 \leq P_1$.

The effect of increasing the focal length (positive values of the adjustment factor α) is thus to make objects appear closer to the viewer. The limiting case for positive values of α is therefore the first case discussed above, as if α becomes too great, the post adjustment parallax P_2 may approach the minimum recommended value for a particular display, at which point the viewer's eyes diverge and can no longer process the images in 3D.

Considering this limiting case, and in the limit of P_2 approaching P_{min}, the following expression can be developed from equation (6), substituting $P_2 = P_{min}$:

$$P_1 = P_{\min} - \frac{S_M t_c f_1}{Z}(1-\alpha) \qquad \text{Equation (7)}$$

Combining equation (7) with equation (5) produces the following expression for the adjustment factor α:

$$\alpha = \frac{S_M h - P_{\min}}{S_M t_c f_1} Z \qquad \text{Equation (8)}$$

Thus the amount by which the cameras may zoom in (limiting positive values of α) is determined by object depth, and maximum positive value for α should not therefore exceed:

$$\alpha = \frac{S_M h - P_{\min}}{S_M t_c f_1} Z_{\min} \qquad \text{Equation (9)}$$

Equation (9) may take different forms if equation (2) above connecting *h*, t_c, and *f* is taken into account.

Returning again to equation (6), it may also be appreciated that $P_2 > P_1$ for $\alpha < 1$. Thus by reducing the focal length (negative values of the adjustment factor α causing the cameras to zoom out of the captured scene) the parallax of the captured images may be increased. This is the reverse of the situation illustrated in Figure 8, with the convergence plane post adjustment being at a lesser depth than the convergence plane before adjustment. Three distinct cases may also be identified for negative values of the adjustment factor α, distinguished by the position of a captured object relative to the initial and post adjustment convergence planes.

Objects that appeared in screen space before the adjustment: $Z \geq Z_{C1}$ had positive initial values of Parallax P_1. For these objects, the parallax post adjustment P_2 is more strongly positive, indicating that these objects appear even farther from the viewer following the adjustment: $0 \leq P_1 < P_2$.

Some objects that appeared in viewer space before the adjustment appear in screen space following adjustment. This change in the type of parallax applies to objects at a depth falling between the initial and post adjustment convergence planes, that is objects at depths Z satisfying the expression: $\alpha Z_{C1} \leq Z < Z_{C1}$. These objects change from having negative values of parallax P_1 before the adjustment to positive values of parallax P_2 post adjustment: $P_1 < 0 \leq P_2$.

Finally, close objects in viewer space before the adjustment remain in viewer space post adjustment but appear less close to the viewer. That is objects having a depth Z less than the post adjustment convergence plane: $Z < \alpha Z_{C1}$, have post adjustment parallax vales P_2 that remain negative but are less strongly negative than the pre adjustment values P_1: $P_1 < P_2 < 0$.

The effect of reducing the focal length (negative values of the adjustment factor α) is thus to make objects appear farther away from the viewer. The limiting case for positive values of α is again the first case discussed above, as if α becomes too small, the post adjustment parallax P_2 may approach the maximum recommended value for a particular display, at which point the viewer's eyes diverge and can no longer process the images in 3D.

Considering this limiting case, and in the limit of P_2 approaching P_{max}, the following expression can be developed from equation (6), substituting $P_2=P_{max}$:

$$P_1 = \mathrm{P}_{\max} - \frac{S_M t_c f_1}{Z}(1-\alpha) \qquad \text{Equation (10)}$$

Combining equation (10) with equation (5) produces the following expression for the adjustment factor α:

$$\alpha = \frac{S_M h - \mathrm{P}_{\max}}{S_M t_c f_1} Z \qquad \text{Equation (11)}$$

Thus the amount by which the cameras may zoom out (limiting negative values of α) is also determined by object depth, and minimum negative value for α should always therefore exceed:

$$\alpha = \frac{S_M h - \mathrm{P}_{\max}}{S_M t_c f_1} Z_{\max} \qquad \text{Equation (12)}$$

By combining the two limiting cases considered above, for positive and negative values of α, the following range for α may be determined:

$$\frac{S_M h - \mathrm{P}_{\max}}{S_M t_c f_1} Z_{\max} \le \alpha \le \frac{S_M h - P_{\min}}{S_M t_c f_1} Z_{\min} \qquad \text{Equation (13)}$$

Equation (13) above defines the range within which the adjustment factor α will result in images captured with a disparity that will result in a parallax on a given display device that falls within the maximum and minimum limits of the display device. The capture parameters Z_{min} and Z_{max} (equivalently d_{min} and d_{max}), h, t_c, f_1 and W_S are known at the capture side as they relate to the setup of the capture apparatus. The limiting display parameters P_{min} and P_{max} and the display width W_D are received at the capture side according to aspects of the present invention. Equation (13) may therefore be used to calculate an adjustment factor range for camera focal length at step 328 of the method 300.

Figure 9 illustrates the effect that may be achieved by adjusting baseline distance at the capture side. Adjusting baseline distance is another way in which depth perception in the captured video images may be adjusted, so rendering the images more comfortable for viewing on a particular display device. Figure 9 illustrates two cameras 10a, 10b of a stereo camera setup. In the first illustrated arrangement of Figure 9, the cameras 10a, 10b are separated by a baseline distance t_{c1}, giving rise to a convergence plane at depth Z_{C1}. In the second illustrated arrangement, the baseline distance has been adjusted to $t_{c2}=\beta\ t_{c1}$, where β is an adjustment factor for the baseline distance and the sensor shift h and focal length f remain unchanged. The changed baseline distance gives rise to a convergence place at a second depth Z_{C2}. In the arrangements illustrated in Figure 9, the adjustment factor β is positive, leading to a convergence plane post adjustment that is at a greater depth than the initial convergence plane.

Simple geometry can be used to prove that $Z_{c2} = \beta Z_{c1}$. The following expressions can also be derived from the above relation and the equations developed above relating capture and display geometry for a stereo 3D setup:

$$\frac{P_2}{P_1} = \frac{Z - \beta Z_{c1}}{Z - Z_{c1}} \quad \text{Equation (14)}$$

and:

$$P_2 - P_1 = \frac{S_M t_{c1} f}{Z}(1-\beta) \quad \text{Equation (15)}$$

From equation (15), it can be shown that $P_2 \leq P_1$ for $\beta \geq 1$. Thus by increasing the baseline distance (positive values of the adjustment factor β) the parallax of the captured images may be reduced. As in the case of adjusted focal length, the same three distinct cases may be identified for positive values of the adjustment factor β, distinguished by the position of a captured object relative to the initial and post adjustment convergence planes. These cases are not discussed again in detail but may be summarized by the following expressions:

For objects at $Z < Z_{C1}$ post adjustment parallax becomes more strongly negative (objects in viewer space appear even closer): $P_2 \leq P_1 < 0$.

For objects at depths between the pre and post adjustment convergence planes $Z_{C1} \leq Z < \beta Z_{C1}$, parallax changes type with adjustment of baseline distance, switching form positive to negative (objects switch from screen to viewer space): $P_2 < 0 \leq P_1$.

For objects at $Z \geq \beta Z_{C1}$ post adjustment parallax becomes less strongly positive (objects in screen space remain in screen space but appear closer): $0 \leq P_2 < P_1$.

The effect of increasing the baseline distance (positive values of the adjustment factor β) is thus to make objects appear closer to the viewer. The limiting case for positive values of β is again the first case discussed above, as if β becomes too great, the post adjustment parallax P_2 may approach the minimum recommended value for a particular display, at which point the viewer's eyes diverge and can no longer process the images in 3D.

Considering this limiting case, and in the limit of P_2 approaching P_{min}, the following expression can be developed from equation (15), substituting $P_2=P_{min}$:

$$P_1 = P_{\min} - \frac{S_M t_{c1} f}{Z}(1-\beta) \qquad \text{Equation (16)}$$

Combining equation (16) with equation (14) above produces the following expression for the adjustment factor β:

$$\beta = \frac{S_M h - P_{\min}}{S_M t_{c1} f} Z \qquad \text{Equation (17)}$$

Thus the amount by which the stereo cameras may be separated (limiting positive values of β) is also determined by object depth, and maximum positive values for β should not therefore exceed:

$$\beta = \frac{S_M h - P_{\min}}{S_M t_{c1} f} Z_{\min} \qquad \text{Equation (18)}$$

As previously, equation (18) may take different forms if equation (2) above connecting h, t_c, and f is taken into account.

Returning again to equation (15), it may also be appreciated that $P_2 > P_1$ for $\beta < 1$. Thus by reducing the baseline distance (negative values of the adjustment factor β) the parallax of the captured images may be increased. This is the reverse of the situation illustrated in Figure 9, with the convergence plane post adjustment being at a lesser depth than the convergence plane before adjustment. As previously, three distinct cases may be identified for negative values of the adjustment factor β, and the limiting case may be developed in a manner substantially analogous to that described above to arrive at a limiting range for values of β over which the parallax of the captured images remains within the boundaries of P_{max} and P_{min}:

$$\frac{S_M h - \mathrm{P}_{\max}}{S_M t_{c1} f} Z_{\max} \le \beta \le \frac{S_M h - P_{\min}}{S_M t_{c1} f} Z_{\min} \qquad \text{Equation (19)}$$

As for adjustment of focal length, the capture parameters Z_{min} and Z_{max} (equivalently d_{min} and d_{max}), h, t_c, f_1 and W_S are known at the capture side, relating to the setup of the capture apparatus. The limiting display parameters P_{min} and P_{max} and the display width W_D are received at the capture side according to aspects of the present invention. Equation (19) may therefore be used to calculate an adjustment factor range for baseline separation at step 328 of the method 300.

Figure 10 illustrates the effect that may be achieved by adjusting camera sensor shift at the capture side. Adjusting sensor shift is another way in which depth perception in the captured video images may be adjusted, so rendering the images more comfortable for viewing on a particular display device. Figure 10 illustrates two cameras 10a, 10b of a stereo camera setup. In the first illustrated arrangement of Figure 10, the cameras 10a, 10b are set up to have a sensor shift h_1, giving rise to a convergence plane at depth Z_{C1}. In the second illustrated arrangement, the sensor shift has been adjusted to $h_2 = \gamma h_1$, where γ is an adjustment factor for the sensor shift and the baseline distance t_c and focal length f remain unchanged. The changed sensor shift gives rise to a convergence place at a second depth Z_{C2}. In the arrangements illustrated in Figure 10, the adjustment factor γ is positive, leading to a convergence plane post adjustment that is at a lesser depth than the initial convergence plane.

Simple geometry can be used to prove that: $Z_{C2} = \frac{Z_{C1}}{\gamma}$. The following expressions can also be derived from the above relation and the equations developed above relating capture and display geometry for a stereo 3D setup:

$$\frac{P_2}{P_1} = \frac{\gamma Z - Z_{c1}}{Z - Z_{c1}} \quad \text{Equation (20)}$$

and:

$$P_2 - P_1 = S_M h_1 (\gamma - 1) \quad \text{Equation (21)}$$

As for the cases of focal length and baseline adjustment, it can be shown from the above equations that $P_2 \geq P_1$ for $\gamma \geq 1$ that $P_2 < P_1$ for $\gamma < 1$. Thus for positive values of the adjustment factor γ parallax is increased, while for negative values of the adjustment facto γ parallax is reduced. In a manner analogous to that described above for focal length and baseline adjustment, key limiting cases can be identified for positive and negative values of γ in which the post adjustment parallax P_2 approaches P_{max} and P_{min}. These limiting cases give rise to the following expressions for limiting positive and negative values of γ:

$$\gamma \leq \frac{P_{max}}{S_M h_1} + \frac{t_c f}{Z_{max} h_1} \quad \text{Equation (22)}$$

and

$$\gamma \geq \frac{P_{min}}{S_M h_1} + \frac{t_c f}{Z_{min} h_1} \quad \text{Equation (23)}$$

Equations (22) and (23) may be combined to arrive at a limiting range for values of γ over which the parallax of the captured images remains within the boundaries of P_{max} and P_{min}:

$$\frac{P_{min}}{S_M h_1} + \frac{t_c f}{Z_{min} h_1} \leq \gamma \leq \frac{P_{max}}{S_M h_1} + \frac{t_c f}{Z_{max} h_1} \quad \text{Equation (24)}$$

As for adjustment of focal length and baseline distance, the capture parameters Z_{min} and Z_{max} (equivalently d_{min} and d_{max}), h, t_c, f_1 and W_S are known at the capture side, as they relate to the setup of the capture apparatus. The limiting display parameters P_{min} and P_{max} and the display width W_D are received at the capture side according to aspects of the present invention. Equation (24) may therefore be used to calculate an adjustment factor range for baseline separation at step 328 of the method 300.

Referring again to Figure 7, after calculating a range for a capture parameter adjustment factor substantially as described above, an adjustment factor is selected from the range in step 330 and applied to the relevant capture parameter in step 340a. An adjustment factor may be selected from the range according to any appropriate selection criteria, as determined for example by a manufacturer or operator of the apparatus. In one example, a factor may be selected from the calculated range so as to require a minimum of adjustment from the existing setup. In another example, a factor may be selected to be an integer value, or to facilitate adjustment of the capture parameter.

Applying the selected adjustment factor may comprise making a physical change to the capture set up, so as to adjust the camera focal length, baseline distance or sensor shift to be equal to the previous value multiplied by the selected adjustment factor. This physical change may be automated or may for example be conducted by an operator of the apparatus under instruction from the apparatus. In some examples in which mutliview video is captured, applying the adjustment factor may comprise selecting or synthesising a view in which the relevant capture parameter is multiplied by the selected adjustment factor. For example, if the selected adjustment factor is an integer value, it may be that a view in which the relevant capture parameter is multiplied by the adjustment factor is available among the recorded views. Applying the selected adjustment factor may therefore comprise selecting this view for sending to the 3D display device. In other examples, a view in which the adjustment factor is applied may not be immediately available, and applying the adjustment factor may comprise synthesising a view in which the relevant capture parameter is multiplied by the selected adjustment factor.

In some examples of the invention, it may be the case that a single video apparatus is configured both to capture 3D images for sending and to receive 3D images for display. This may be the case for example in a 3D video conferencing arrangement, in which simultaneous capture of images for sending and display of received images is required. An example of such an arrangement is illustrated in Figure 13, which shows a system 800 in which two video apparatus 600, 700 and associated display screens 680, 780 exchange limiting display parameters and captured video images. The exchange of limiting display parameters enables adjustment of capture parameters at each apparatus and so ensures that the captured video images may be comfortably viewed in 3D on the relevant display screens.

It may also be the case that multiple parties are involved in a single video conferencing session, and therefore that video captured at a single apparatus is to be sent to multiple destinations. Video may also be received at the apparatus from multiple destinations for simultaneous display on a 3D display associated with the apparatus. According to aspects of the present invention, a video apparatus may be configured to receive limiting display parameters from multiple display devices to which captured video is to be sent, to identify from among the received limiting parameters those parameters representing the most limiting scenario and to select those parameters for subsequent processing. One way in which embodiments of the present invention may address the multi party scenario, as well as optimising adjustment of capture parameters, is discussed below with reference to Figure 11.

Figure 11 illustrates steps in another method 400 for conducting in an apparatus configured to capture 3D video images for display on a 3D display device in accordance with an embodiment of the present invention. The method 400 illustrated in Figure 11 is suitable for implementation for example in a setup in which a single video apparatus is configured both to capture and receive video images for display, and to cooperate with multiple other video apparatus devices in a multi party arrangement such as multi party 3D video conferencing.

Referring to Figure 11, in a first step 405, the apparatus sends a message containing, *inter alia*, the display width W_D and maximum and minimum parallax P_{max}, P_{min} for a 3D display device with which the apparatus is associated. The message may be in one of a number of suitable formats and exchange of the message may form part of the setup procedures for establishing exchange of video content and other signals. In some examples the message may be a Session Description Protocol (SDP) message or a Realtime Transport Control Protocol (RTCP) message or an H.323 message. In the illustrated example, the message is an SDP message. The SDP message containing W_D, P_{max} and P_{min} is sent to all parties from whom the apparatus will be receiving video images for display.

In a second step 410, the apparatus receives captured video images from other parties for display on its associated 3D display device. It will be appreciated that the step of receiving images for display may be ongoing, and that images may be received and displayed concurrently with the following steps described below, which relate to the process of capturing images at the video apparatus.

In a next step 420a, the apparatus receives messages from all parties to whom captured video images will be sent. As discussed above, these messages may take various different forms but in the illustrated example take the form of SDP messages. At step 420b, the apparatus extracts from the received messages the display parameters W_D, P_{max} and P_{min}. The apparatus then identifies, at step 422, the extracted display parameters representing the most limiting display situation. It will be appreciated that in many multi party exchange situations, the 3D display devices to which video images are sent may vary considerably, and the limiting display parameters associated with those display devices may thus also vary. In order to ensure that captured video images are suitable for display on all of the destination display devices, the apparatus identifies the most limiting parameters, associated with the most limiting display device, and proceeds to adjusted capture parameter(s) on the basis of this most limiting set of constraints. For example, the moist limiting value of W_D may be the smallest value. The most limiting value of P_{max} may also be the smallest value of P_{max}, and the most limiting value of P_{min} may be the largest value of P_{min}. By identifying the combination of W_D, P_{max} and P_{min} that represent the most limiting display situation, and using these parameters for subsequent calculations, the apparatus ensures that captured video images are suitable for all destination display devices.

Having identified the most limiting of the received display parameters at step 422, the apparatus then performs a check to determine whether or not adjustment of capture parameters is necessary. This may involve checking the disparity for a captured image or images to determine whether or not that disparity will result in a display parallax on the most limiting display device that is within the identified limiting P_{max} and P_{min} values. It will be appreciated that values of disparity (or parallax on the display side) may be assessed for each point on each object of an image. In practical terms, disparity or parallax may be calculated for each pixel of an image to be displayed. The apparatus thus checks, at step 424 the disparity (or parallax) for each pixel of an image or images. If the disparity for all pixels results in a display parallax on the most limiting display device that is within the identified limiting values, then no adjustment of capture parameters is necessary. In practice, if only one or a very small number of pixels are found to have disparity/parallax outside the limiting values, this is highly unlikely to affect viewer experience, and adjustment of capture parameters in an effort to ensure 100% of pixels have values falling within the limiting values may be counter productive. A threshold value may therefore be established for the number or percentage of pixels which must have disparity/parallax falling within the identified limits for an image to be considered acceptable. This threshold may be set at any limit deemed appropriate for a particular application or display device and may for example be in the range 50% - 99% of pixels. If at step 424 the apparatus determines that the number or percentage of pixels having disparity/parallax within the limiting values is above the threshold value, (yes at step 424) then the apparatus determines that no adjustment of capture parameters is necessary, and the apparatus proceeds directly to send captured video images at step 460.

If the apparatus determines at step 424 that the number or percentage of pixels having disparity/parallax within the identified limiting values is less than the threshold value (No at step 424) then the apparatus deems that adjustment of capture parameters is necessary and proceeds to select a parameter for adjustment at step 426. The apparatus may be configured with a hierarchy or preferred order in which capture parameters are selected for adjustment. In some examples, the preferred order for selection may comprise: (1) baseline distance, (2) sensor shift, (3) focal length. Baseline distance may be the most desirable capture parameter to adjust in a first instance as adjusting the baseline distance involves moving a single camera, and does not involve changing any of the internal set up of a pair of stereo cameras. Focal length may be the least desirable capture parameter for adjustment as changing the focal length has the effect of zooming in or out of the scene, thus changing what is viewed in the scene in addition to the depth perception of the scene.

In some examples, the apparatus may thus first check whether any capture parameter has already been adjusted (as discussed further below) and may then consult a memory which may be programmed with a preferred order to determine which capture parameter should be adjusted.

Having selected a capture parameter for adjustment in step 426, the apparatus proceeds to calculate an adjustment factor range for the parameter in step 428. This calculation is conducted substantially as discussed above with reference to Figures 7 to 10, using the identified most limiting received parameters W_D, P_{max}, P_{min} in equation (13), (19) or (24). After calculating a range for the adjustment factor, a value for the adjustment factor is selected from the range at step 430 in accordance with criteria which may be programmed by a manufacturer of the apparatus or may be determined or selected by an operator of the apparatus as discussed above.

After selecting an adjustment factor at step 430, the apparatus then checks, at step 432, whether or not the selected adjustment factor is within acceptable limits for the capture apparatus. In some situations, for example where a highly limiting display device is to be accommodated, it may be the case that some or all of the calculated adjustment factor range may correspond to an adjustment of a capture parameter that is outside the acceptable limits of the capture apparatus. For example some or all of a calculated range may correspond to a baseline distance that is longer than can be accommodated, or to a greater sensor shift than can be achieved with the existing cameras.

If it is discovered in step 432 that the selected adjustment factor is outside acceptable apparatus limits (No in step 432), then the apparatus proceeds to select an adjustment factor that is as close as possible to the calculated range while remaining within the acceptable apparatus limits. This adjustment factor is then applied to the capture parameter in step 436 and the apparatus returns to step 426 to select another parameter for adjustment. This flow of events represents a situation where the adjustment required to accommodate a display device is too great to be achieved by changing only one capture parameter. A part of the adjustment is therefore accomplished by adjusting a first capture parameter and the rest of the adjustment is accomplished by changing a second and if necessary a third capture parameter. In calculating an adjustment factor range for the second or third parameter in step 428, the adjusted value for the first (and if appropriate second) capture parameter(s) is taken into account, in order to ensure that the calculation for the second capture parameter reflects the progress already made towards achieving the adjustment required to capture images that will allow for comfortable 3D viewing on the most limiting 3D display device.

Returning to step 432, if it is determined that the selected adjustment factor is within acceptable limits for the capture apparatus (yes at step 432), then the apparatus proceeds to apply the selected adjustment factor to the relevant capture parameter in step 440a, resulting in a capture parameter that is multiplied by the adjustment factor. As discussed above, application of the selected adjustment factor may comprise making physical changes to the camera setup in a stereo setup or may comprise selection or synthesis of appropriate views in a multiview setup.

After applying the selected adjustment factor in step 440a, the apparatus then checks the disparity/parallax of images captured with the new adjusted capture parameter. At step 442, the apparatus checks whether the percentage or number of pixels falling within the identified limits is greater than before the adjustment. If this is not the case (No in step 442) then the adjustment has not improved the situation and the adjustment is discarded at step 444. After discarding the adjustment, the apparatus checks whether adjustment of all capture parameters has yet been attempted at step 446. If adjustment of all parameters has not yet been attempted (No at step 446), the apparatus returns to step 426 to select a new parameter for adjustment. If however adjustment of all possible capture parameters has already been attempted (Yes at step 446), this indicates that it has not been possible to adjust capture parameters in such a way as to achieve comfortable 3D viewing on the most limiting display device. In this instance the apparatus reverts to sending 2D video at step 448.

Returning to step 442, if the apparatus determines at step 442 that the number or percentage of pixels falling within the identified limits is greater than before the adjustment (Yes at step 442) then the adjustment has improved the situation, and the apparatus then checks at step 450 whether or not the number or percentage of pixels falling within the identified limits is above the threshold value for an acceptable image. If the number or percentage of pixels is not above the threshold value (No at step 450), then the apparatus reverts to step 446 to check whether adjustment of all parameters has been attempted and the process flow is followed through steps 426 (select new parameter) or step 448 (revert to 2D video) as appropriate and as discussed above.

If at step 450 it is determined that the number or percentage of pixels is above the threshold value (Yes at step 450) this indicates that the adjustment or adjustments have resulted in capture of images that will afford comfortable 3D viewing on the most limiting of the display devices to which the images are to be sent. The images may therefore be sent to all destination display devices in step 460. While sending images for display, the apparatus continues to check for receipt of a new message containing updated limiting display parameters. Although exchange of such messages may primarily be conducted at the start of a session, periodic update of limiting parameters may be appropriate as parties enter or leave a session or changes are made to a display setup.

The above described method may be conducted in an apparatus as illustrated in Figure 12, for example according to instructions received from a computer program stored on a computer readable medium. Figure 12 illustrates functional units of an apparatus which may be realised in any combination of hardware and/or software. As illustrated in Figure 12, the apparatus comprises a receiving unit 520, sending unit 560, a first checking unit 524 and an adjusting unit 540. The adjusting unit comprises a calculating unit 528, a selecting unit 530, a second checking unit 532 and an application unit 540a.

The receiving unit 520 is configured to receive messages from other apparatus and to extract limiting display parameters from such messages. The receiving unit may further comprise an identification unit 522 for identifying limiting display parameters representing the most limiting case display device. The receiving unit may also be configured to receive captured video images from other apparatus. The sending unit 560 is configured to send captured video images to other apparatus and may also be configured to send received video images to an associated 3D display device for display. The sending unit may also be configured to send a message or messages containing limiting display parameters for the associated 3D display device. The first checking unit 524 is configured to check the number or percentage of pixels in an image having disparity/parallax within the limits indentified by the identification unit 522 and to compare this number or percentage to a previous value and to a threshold value as appropriate and as discussed above. The calculating unit 528 is configured to calculate an adjustment factor range for a capture parameter and the selecting unit 530 is configured to select a factor from the calculated range. The second checking unit is configured to check whether or not the selected adjustment factor is within acceptable apparatus limits and the application unit 540a is configured to apply the selected adjustment factor.

Embodiments of the present invention thus provide a method, computer program product and apparatus that ensure images captured at an apparatus may be comfortably viewed in 3D on a destination 3D display device. By signalling limiting display parameters of the destination display device to the video apparatus, the invention allows for the adjustment of capture parameters at the video apparatus, ensuring the images captured and sent to the destination display device are compatible with the limits of 3D viewing of the display device. The formulae for calculating a range of capture parameter adjustment factors corresponding to the limiting display parameters of the destination display device are developed in the present disclosure and set out above.

The method of the present invention may be implemented in hardware, or as software modules running on one or more processors. The method may also be carried out according to the instructions of a computer program, and the present invention also provides a computer readable medium having stored thereon a program for carrying out any of the methods described herein. A computer program embodying the invention may be stored on a computer-readable medium, or it could, for example, be in the form of a signal such as a downloadable data signal provided from an Internet website, or it could be in any other form.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. The word “comprising” does not exclude the presence of elements or steps other than those listed in a claim, “a” or “an” does not exclude a plurality, and a single processor or other unit may fulfil the functions of several units recited in the claims. Any reference signs in the claims shall not be construed so as to limit their scope.

CLAIMS

1. A method for conducting in an apparatus configured to capture 3D video images for display on a 3D display device, the method comprising:

receiving a limiting display parameter associated with the 3D display device;

adjusting a capture parameter of the video apparatus according to the received limiting display parameter; and

sending video images captured with the adjusted capture parameter to the 3D display device for display.

2. A method as claimed in claim 1, wherein the limiting display parameter comprises at least one of a maximum and/or minimum display parallax.

3. A method as claimed in any one of the preceding claims, wherein the capture parameter comprises one of focal length, baseline separation or sensor shift.

4. A method as claimed in any one of the preceding claims, wherein the apparatus is associated with a 3D display device and is configured to receive 3D images for display from a second video apparatus, the method further comprising:

sending a limiting parameter of the associated 3D display device to the second video apparatus.

5. A method as claimed in any one of the preceding claims, further comprising:

receiving a limiting display parameter associated with at least one other 3D display device; and

sending video images captured with the adjusted capture parameter to the other 3D display device for display; wherein:

adjusting a capture parameter of the video apparatus comprises:

identifying which of the received limiting display parameters represents a greater constraint on capture parameters; and

adjusting the capture parameter according to the identified limiting display parameter.

6. A method as claimed in any one of the preceding claims, wherein adjusting a capture parameter comprises:

calculating an adjustment factor range for the capture parameter, the calculation based upon the received limiting display parameter and the capture parameter;

selecting an adjustment factor from the calculated range; and

applying the selected adjustment factor to the capture parameter.

7. A method as claimed in claim 6, wherein the adjustment factor range comprises values of an adjustment factor resulting in a display parameter in accordance with the received limiting display parameter.

8. A method as claimed in claim 6 or 7, further comprising receiving a display screen dimension of the 3D display device, and wherein the calculation is also based upon the received display screen dimension.

9. A method as claimed in any one of claims 6 to 8, wherein applying the selected adjustment factor comprises changing a physical capture arrangement such that the capture parameter is multiplied by the selected adjustment factor.

10. A method as claimed in any one of claims 6 to 9, wherein applying the selected adjustment factor comprises selecting a view in which the capture parameter is multiplied by the selected adjustment factor, or, if such a view is not available, synthesizing a view in which the capture parameter is multiplied by the selected adjustment factor.

11. A method as claimed in any one of claims 6 to 10, wherein the calculation is also based upon at least one other capture parameter.

12. A method as claimed in claim 11, wherein the at least one other capture parameter comprises: maximum depth, minimum depth, maximum disparity, minimum disparity, sensor shift, focal length, baseline separation or sensor width.

13. A method as claimed in any one of claims 6 to 12, further comprising:

checking that the selected adjustment factor is within an acceptable apparatus limit; and

if the selected adjustment factor is not within an acceptable apparatus limit:

(i) selecting an adjustment factor within an acceptable apparatus limit that is closest to the calculated range;

(ii) applying the selected adjustment factor to the capture parameter; and

(iii) conducting the steps of calculating an adjustment factor range, selecting an adjustment factor from the calculated range, and applying the selected adjustment factor for at least one other capture parameter of the video apparatus, the calculation based upon the received limiting display parameter, the adjusted capture parameter and the at least one other capture parameter.

14. A computer program product which, when run on a computer, causes the computer to carry out a method according to any one of the preceding claims.

15. A video apparatus configured to capture 3D video images for display on a 3D display device, the apparatus comprising:

a receiving unit configured to receive a limiting display parameter associated with the 3D display device;

an adjusting unit configured to adjust a capture parameter of the video apparatus according to the received limiting display parameter; and

a sending unit configured to send video images captured with the magnified capture parameter to the 3D display device for display.

16. An apparatus as claimed in claim 15, wherein the apparatus is associated with a 3D display device and is configured to receive 3D images for display from a second video apparatus, and wherein the sending unit is configured to send a limiting parameter of the associated 3D display device to the second video apparatus.

17. An apparatus as claimed in claim 15 or 16, wherein the receiving unit is further configured to receiving a limiting display parameter associated with at least one other 3D display device; and the sending unit is further configured to send video images captured with the adjusted capture parameter to the other 3D display device for display; and wherein the receiving unit further comprises an identification unit configured to identify which of the limiting display parameters received by the receiving unit represents a greater constraint on capture parameters.

18. An apparatus as claimed in any one of claims 15 to 17, wherein the adjusting unit comprises:

a calculating unit configured to calculate an adjustment factor range for the capture parameter of the video apparatus, the calculation based upon the received limiting display parameter and the capture parameter;

a selecting unit configured to select an adjustment factor from the calculated range; and

an application unit configured to apply the selected adjustment factor to the capture parameter.

19. An apparatus as claimed in claim 18, wherein the receiving unit is further configured to receive a display screen dimension, and wherein the calculation unit is further configured to base the calculation of magnification factor range upon the received display screen dimension.

20. An apparatus as claimed in claim 18 or 19, wherein the application unit is configured to change a physical capture arrangement such that the capture parameter is multiplied by the selected adjustment factor.

21. An apparatus as claimed in any one of claims 18 to 20, wherein the application unit is configured to select a synthesized view in which the capture parameter is multiplied by the selected adjustment factor, and, if such a view is not available, to synthesize a view in which the capture parameter is multiplied by the selected adjustment factor.

22. An apparatus as claimed in any one of claims 18 to 21, wherein the calculating unit is further configured to base the calculation upon at least one other capture parameter.

23. An apparatus as claimed in claim 22, wherein the at least one other capture parameter comprises one of: maximum depth, minimum depth, maximum disparity, minimum disparity, sensor shift, focal length, baseline separation or sensor width.

24. An apparatus as claimed in any one of claims 18 to 23, wherein the adjusting unit further comprises:

a second checking unit configured to check that the selected adjustment factor is within an acceptable apparatus limit; and if the selected adjustment factor is not within an acceptable apparatus limit, configured to instruct the selecting unit to select an adjustment factor within an acceptable apparatus limit that is closest to the calculated range; and to instruct the calculating, selecting and application units to calculate an adjustment factor range, select an adjustment factor from the calculated range, and apply the selected adjustment factor for at least one other capture parameter of the video apparatus, the calculation based upon the received limiting display parameter, the adjusted capture parameter and the at least one other capture parameter.

25. A system for 3D video capture and display, comprising:

a first video apparatus configured to capture 3D video images; and

a second video apparatus associated with a 3D display device configured to display 3D video images; wherein the second video apparatus is configured to:

receive 3D images for display from the first video apparatus; and

send a limiting display parameter of the 3D display device to the first video apparatus; and wherein the first video apparatus is configured to:

receive the limiting display parameter from the second video apparatus;

adjust a capture parameter of the first video apparatus; and

send video images captured with the adjusted capture parameter to the second video apparatus for display.

Fig. 1

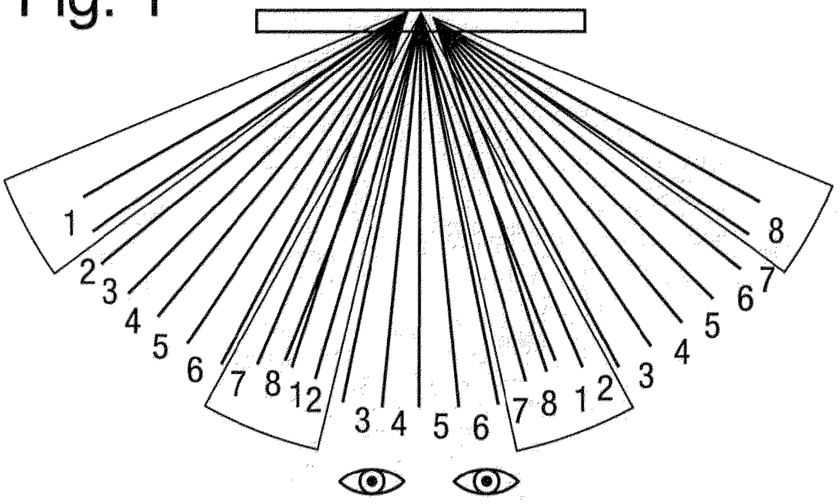

1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8

Fig. 2

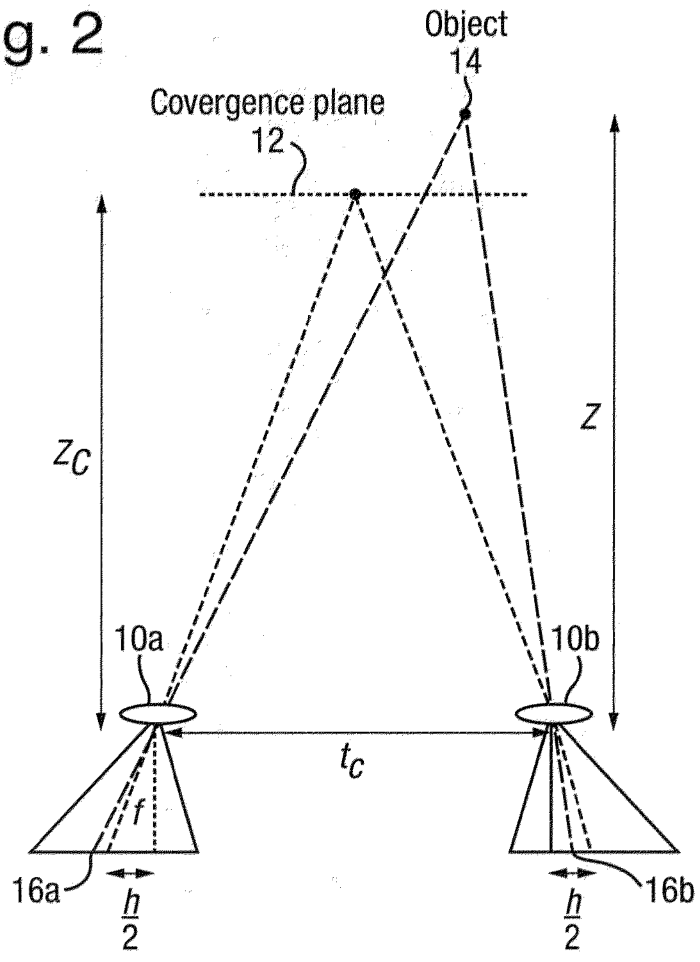

Object
14
Covergence plane
12
z_C
Z
10a
10b
t_C
f
16a
16b
$\frac{h}{2}$
$\frac{h}{2}$

Fig. 3(a)

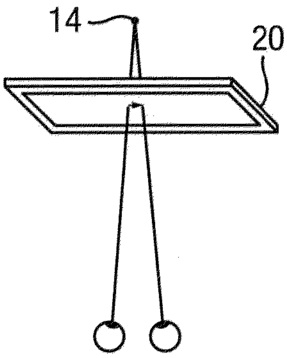


Fig. 3(b)

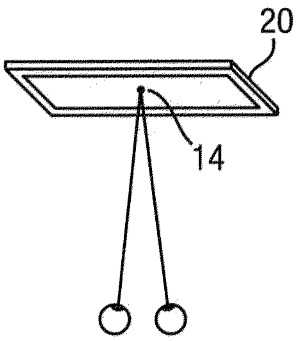


Fig. 3(c)

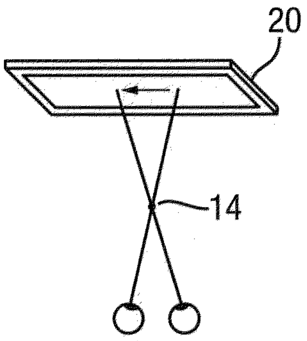


Fig. 4

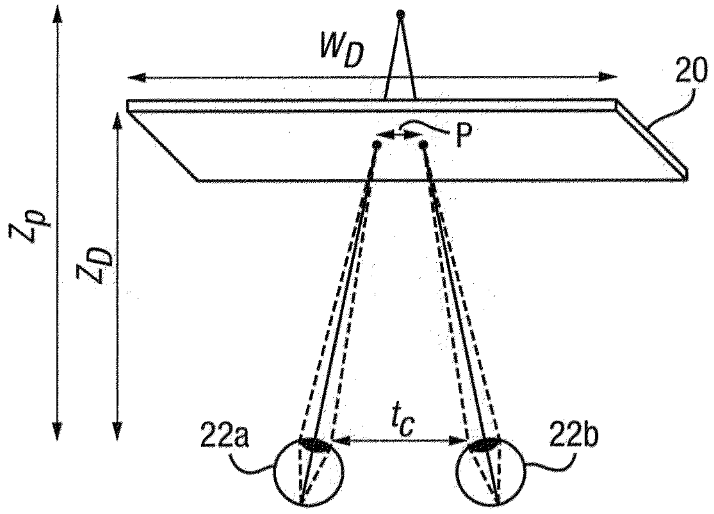


Fig. 5

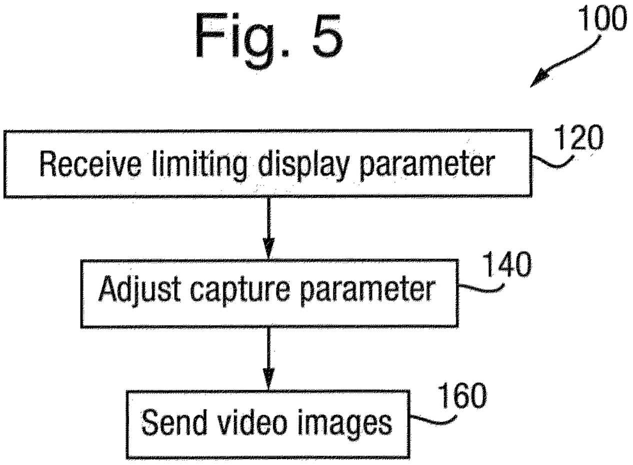


Fig. 6

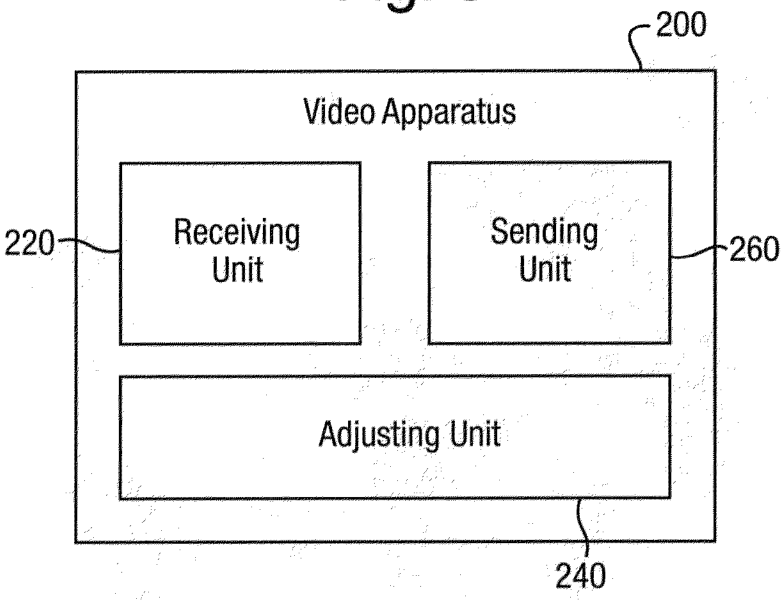

200
Video Apparatus
220
Receiving Unit
Sending Unit
260
Adjusting Unit
240

Fig. 7

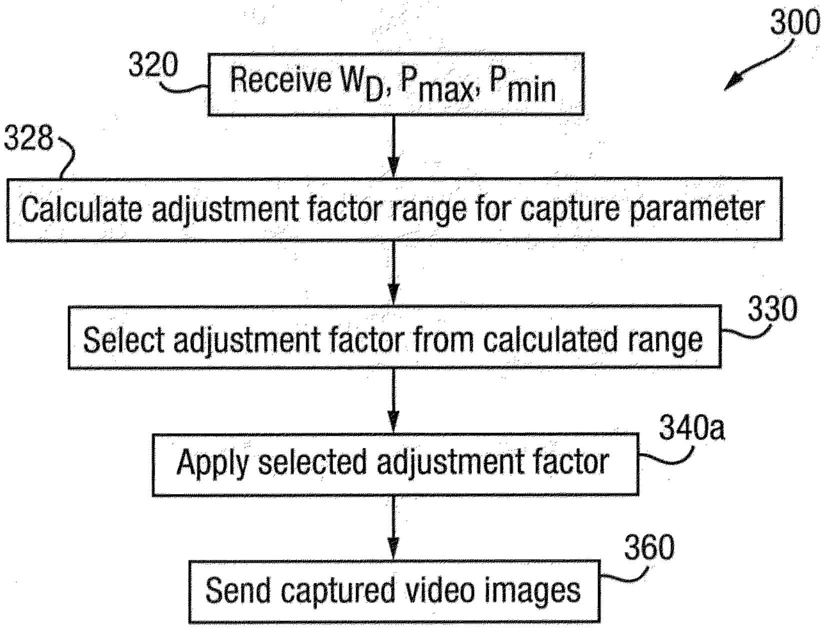

300
320
Receive W_D, P_{max}, P_{min}
328
Calculate adjustment factor range for capture parameter
330
Select adjustment factor from calculated range
340a
Apply selected adjustment factor
360
Send captured video images

Fig. 8

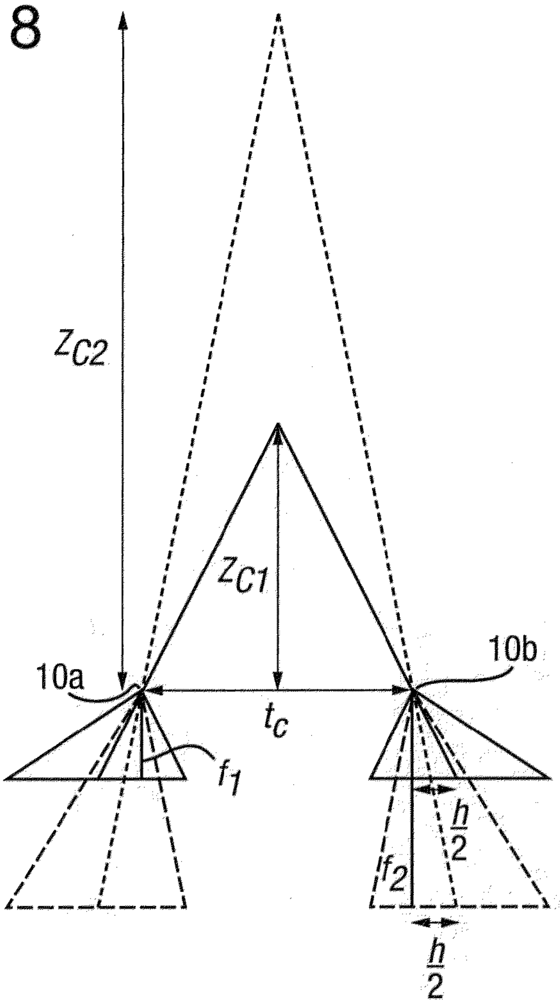

z_{C2}
z_{C1}
10a
10b
t_c
f_1
f_2
$\frac{h}{2}$
$\frac{h}{2}$

Fig. 9

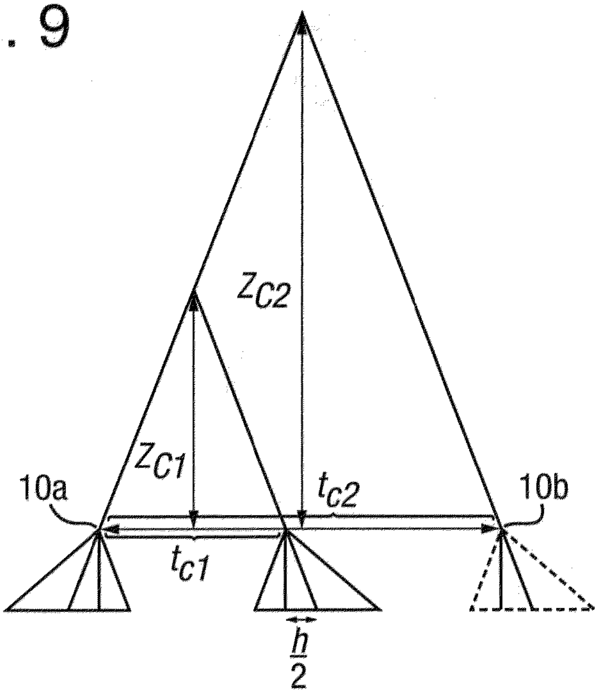
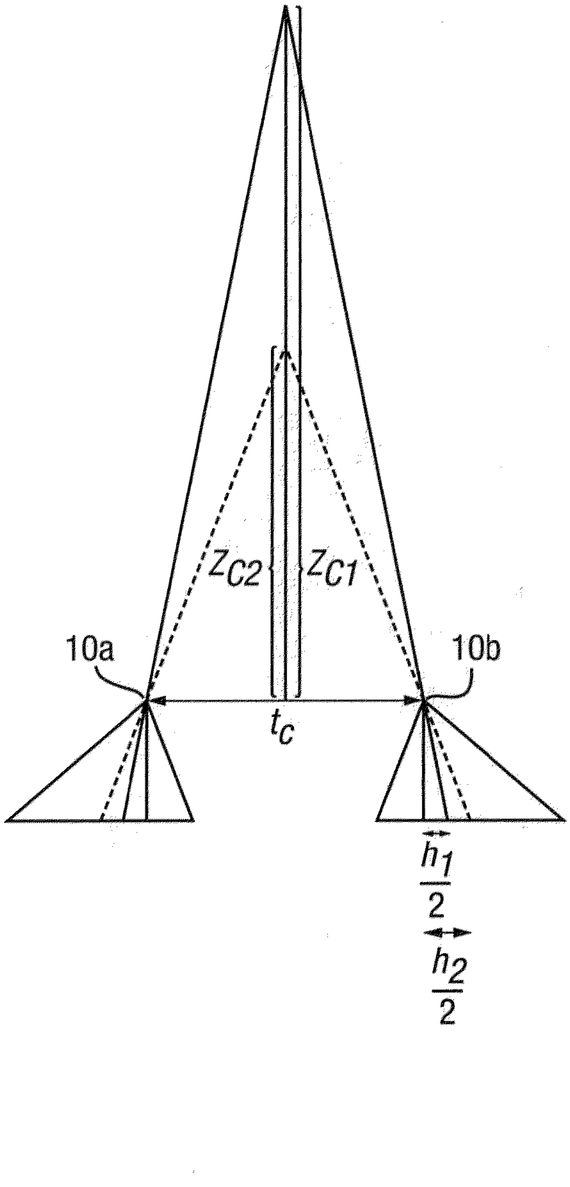

z_{C2}
z_{C1}
10a
10b
t_{c2}
t_{c1}
$\frac{h}{2}$

Fig. 10



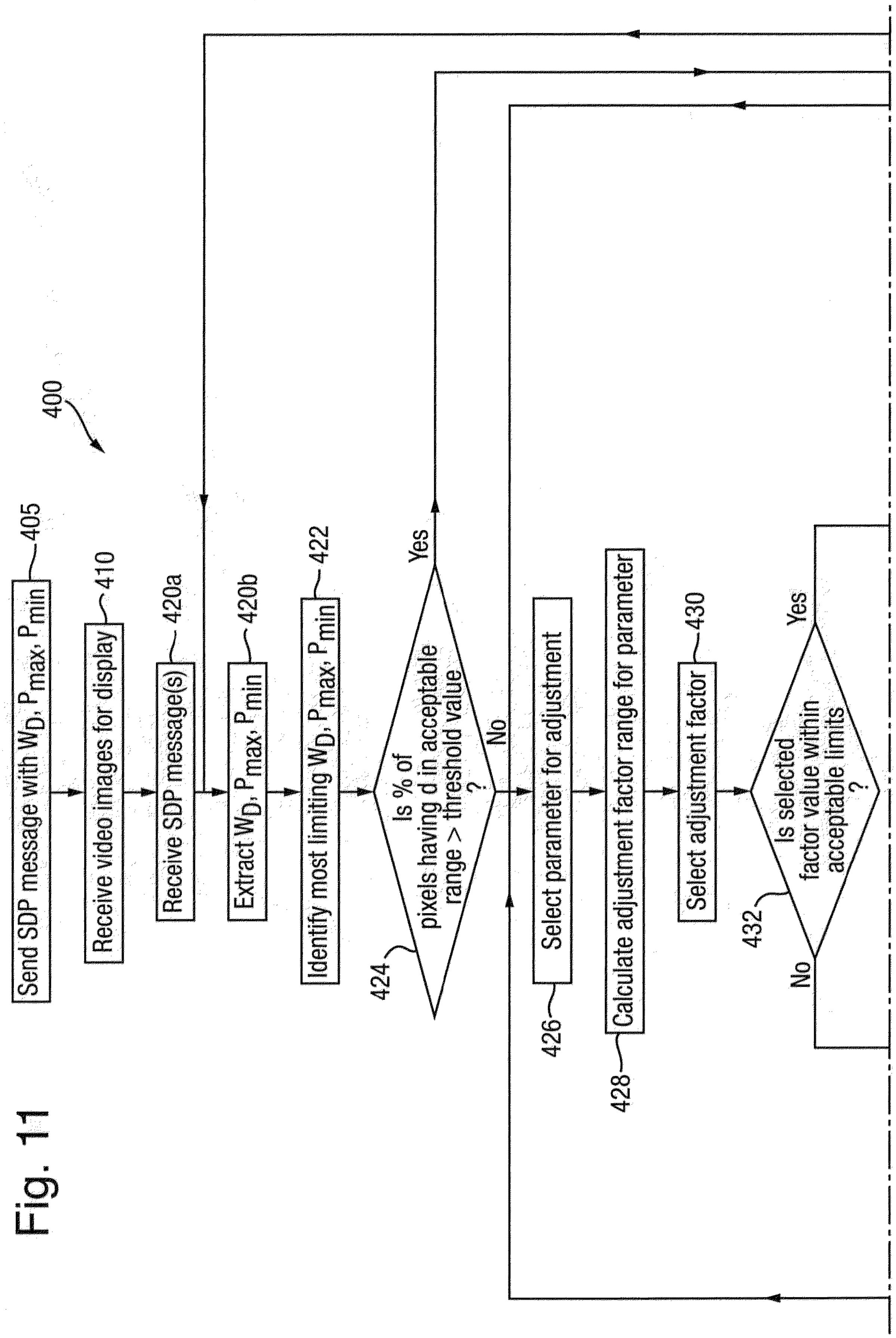

400
Send SDP message with W_D, P_{max}, P_{min}
405
Receive video images for display
410
Receive SDP message(s)
420a
Extract W_D, P_{max}, P_{min}
420b
Identify most limiting W_D, P_{max}, P_{min}
422
Is % of pixels having d in acceptable range > threshold value ?
424
Yes
No
Select parameter for adjustment
426
Calculate adjustment factor range for parameter
428
Select adjustment factor
430
Is selected factor value within acceptable limits ?
432
Yes
No

Fig. 11

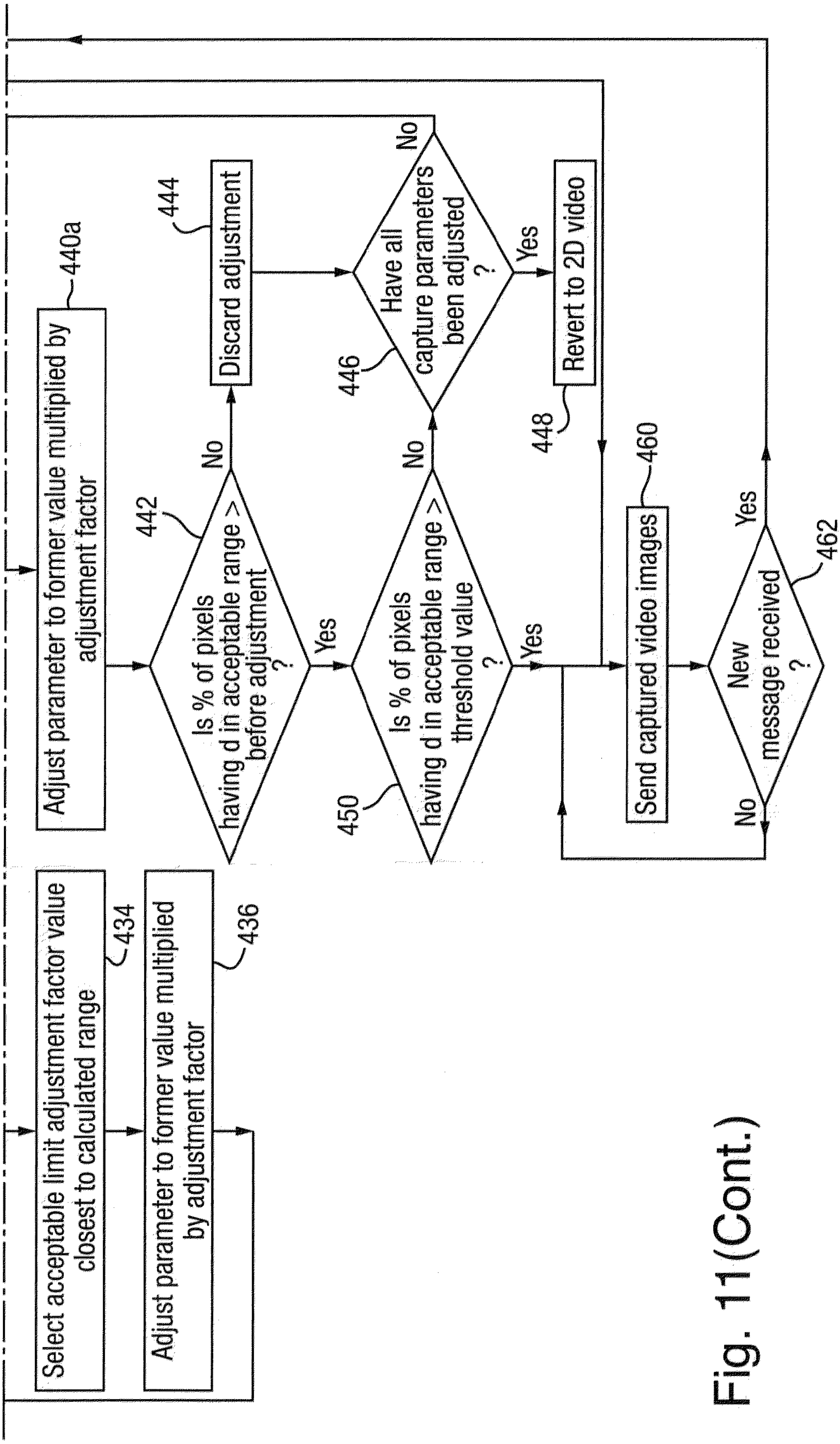

Select acceptable limit adjustment factor value closest to calculated range
434
Adjust parameter to former value multiplied by adjustment factor
436
Adjust parameter to former value multiplied by adjustment factor
440a
Is % of pixels having d in acceptable range > before adjustment ?
442
Yes
No
Discard adjustment
444
Have all capture parameters been adjusted ?
446
No
Yes
Revert to 2D video
448
Is % of pixels having d in acceptable range > threshold value ?
450
Yes
No
Send captured video images
460
New message received ?
462
Yes
No

Fig. 11(Cont.)

Fig. 12

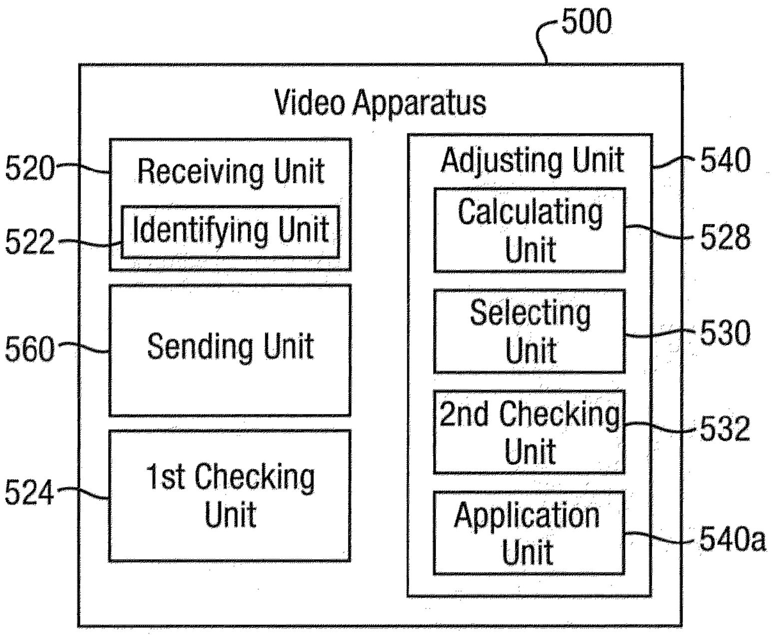
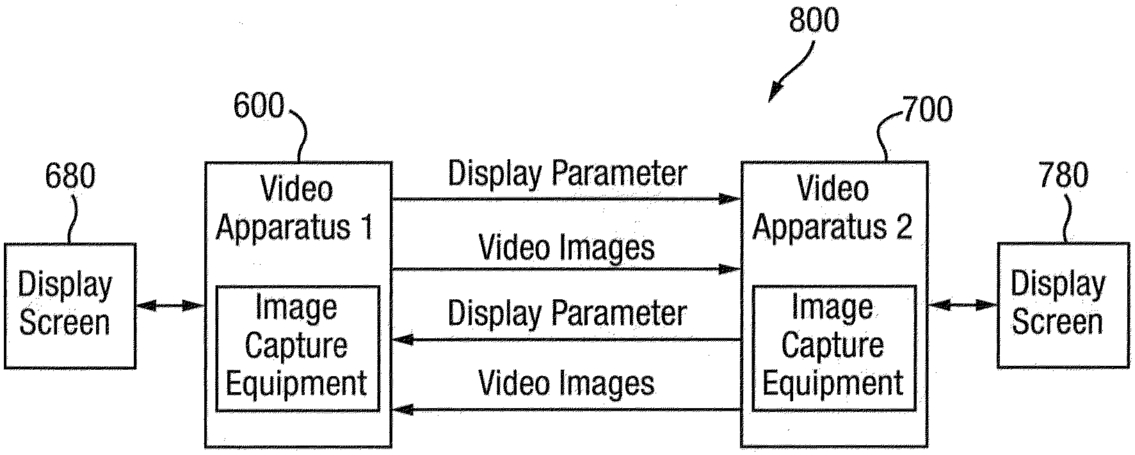

500
Video Apparatus
520
Receiving Unit
522
Identifying Unit
560
Sending Unit
524
1st Checking Unit
Adjusting Unit
540
Calculating Unit
528
Selecting Unit
530
2nd Checking Unit
532
Application Unit
540a

Fig. 13


800
600
700
680
780
Display Screen
Video Apparatus 1
Image Capture Equipment
Display Parameter
Video Images
Display Parameter
Video Images
Video Apparatus 2
Image Capture Equipment
Display Screen

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/053704

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N13/02 H04N7/14 H04N7/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 085 769 A2 (SHARP KK [JP]) 21 March 2001 (2001-03-21) paragraph [0020] - paragraph [0022] paragraph [0045] - paragraph [0048]; figure 3 paragraph [0086] -----	1-25
X	WO 2011/121397 A1 (NOKIA CORP [FI]; POCKETT LACHLAN [FI]) 6 October 2011 (2011-10-06) page 28, line 28 - page 29, line 16; figure 9 -----	1-25
X	EP 1 089 573 A2 (SHARP KK [JP]) 4 April 2001 (2001-04-04) paragraph [0025] - paragraph [0031] paragraphs [0081], [0092], [0096]; figure 5 ----- -/--	1-25

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
28 March 2013

Date of mailing of the international search report
12/04/2013

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer
Wahba, Alexander

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/053704

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/019926 A1 (REAL D [US]; ROBINSON MICHAEL G [US]) 18 February 2010 (2010-02-18) paragraph [0030] - paragraph [0040] -----	1,14,15
A	WO 2011/071478 A1 (HEWLETT PACKARD DEVELOPMENT CO [US]; GAGNERAUD ERIC [US]) 16 June 2011 (2011-06-16) figure 2 -----	4,16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/053704

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1085769 A2	21-03-2001	EP 1085769 A2	21-03-2001
		JP 2001142166 A	25-05-2001
		US 6512892 B1	28-01-2003
WO 2011121397 A1	06-10-2011	CN 102835116 A	19-12-2012
		EP 2532166 A1	12-12-2012
		WO 2011121397 A1	06-10-2011
EP 1089573 A2	04-04-2001	EP 1089573 A2	04-04-2001
		GB 2354389 A	21-03-2001
		GB 2354391 A	21-03-2001
		JP 3568195 B2	22-09-2004
		JP 2001148869 A	29-05-2001
		US 6798406 B1	28-09-2004
WO 2010019926 A1	18-02-2010	EP 2319016 A1	11-05-2011
		US 2010039502 A1	18-02-2010
		US 2013050437 A1	28-02-2013
		WO 2010019926 A1	18-02-2010
WO 2011071478 A1	16-06-2011	US 2012120183 A1	17-05-2012
		WO 2011071478 A1	16-06-2011