A New Configuration of LCD Projectors for Polarized Stereoscopic Projection with Improved Light Efficiency

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Abstract

A new configuration of LCD projectors for polarized stereoscopic projection having no light loss in the polarization process is suggested. In the proposed system, two polarizing filters that are employed in the conventional LCD polarized stereoscopic projection system causing additional light loss and image distortion are excluded by taking into account of polarization property of the LCD projector and image processing techniques. From some experimental results by using the Type-1 LCD projectors of NEC MT 1060R, light loss of the proposed system occurring in the polarization process is found to be zero and the resultant stereoscopic video image projected from this system is also found to be 213%, 75% and 300% brighter than those projected from the conventional Type-1 LCD projector-based, Type-2 LCD projector-based and Type-3 projector-based systems, respectively.

1. Introduction

In general, projectors mostly used for polarized stereoscopic projection can be classified into three types depending on the polarization state of their outputs[1][2]. The majority of commercial LCD(liquid crystal display) projectors has the linear polarized output with two colors in one direction and the other color in an orthogonal direction, which are classified as Type-1 LCD projector here. Some other LCD projectors also have the linear polarized outputs with all colors in the same directions, which are classified as Type-2 LCD projector here. On the contrary to the LCD projectors, the CRT(cathode ray tube), DMD(digital micro-mirror device) and DLP(digital light processing) projectors have the unpolarized outputs, which are classified as Type-3 projector here.

In case of Type-3 projector, two polarizers must be placed in front of the projectors for the two views to be polarized in the orthogonal directions, in which much concern is not given to the orientation of the polarizers because the outputs of CRT or DMD/DLP projectors are unpolarized. But, in cases of Type-1 and Type-2 LCD projectors, the orientation of the polarizer is very important because the output of LCD projector has already been polarized. Moreover, light loss of LCD polarized stereoscopic projection highly depends on the configuration of LCD projectors for polarized stereoscopic projection.

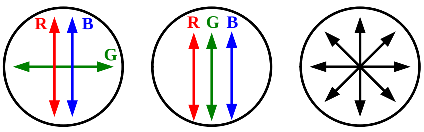
Recently, A. Woods[1] discussed various configurations of the commercial projectors for polarized stereoscopic projection and evaluated their performances in terms of light loss. V. Elkhov and Y. Ovechkis[3] also suggested a LCD polarized stereoscopic projection method for reducing the light loss occurred in the process of polarization.

In this paper, new configurations of LCD projectors for polarized stereoscopic projection without light loss in the process of polarization are proposed[4] and tested through experiments. In the proposed system, two polarizing filters or waveplates, which have been employed in the conventional LCD polarized stereoscopic projection systems causing an additional light loss and image distortion, are excluded by taking into account of polarization property of the LCD projectors and image processing techniques, so that maximum light efficiency can be obtained from the proposed method. This proposed scheme can be applied to both of Type-1 LCD and Type-2 LCD projectors.

Through experimenting with Type-1 LCD projectors of NEC MT 1060R, performance of the proposed system is also evaluated in terms of light efficiency, and its results are discussed and compared with those of the conventional systems.

2. Proposed LCD Polarized Stereoscopic Projection System for the Case of Type-1 LCD Projector

As mentioned above, commercial projectors mostly used for polarized stereoscopic projection can be classified into three types; Type-1 LCD, Type-2 LCD, Type-3 according to the output polarization states of them. Figure 1 shows the output polarization states of three types of projectors. Type-1 LCD projectors have the linear polarized outputs with two colors of red and blue in the vertical direction and the other color of green in the horizontal direction. Type-2 LCD projectors have the linear polarized outputs with all colors in the same directions and Type-3 projectors have the unpolarized outputs.

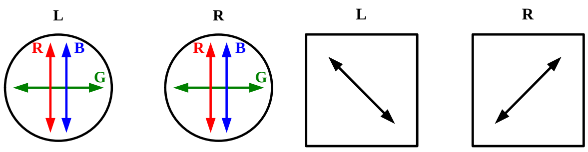


(a) (b) (c)

Fig. 1 Illustration of output polarization of three types of projector (a) Type-1 LCD (b) Type-2 LCD (c) Type-3

For these three types of commercial projectors to be used for polarized stereoscopic projection, various configurations of optical polarizers must be employed to obtain correct polarization output and color balance with minimal light loss and color distortion.

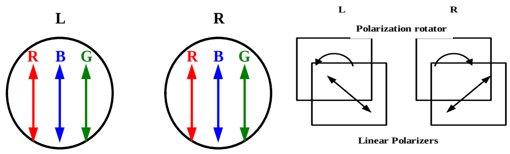
In case of Type-1 LCD projectors, which are mostly consisted of three LCD panels, two linear polarizers must be mounted at either + 45° or – 45° in front of the right and left projector for achieving the correct orthogonal polarization and color balance as shown in Fig. 2(b). Here, two circular polarizers (one is clockwise, the other is counterclockwise) with their axis at +/-45° could be also used instead of two linear polarizers.



(a) (b)

Fig. 2 Method of linearly polarized stereoscopic projection with Type-1 LCD projectors (a) Polarized outputs of Type-1 LCD (b) Linear polarizers

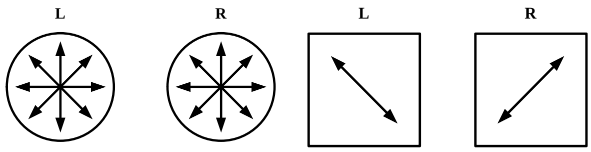
In case of Type-2 LCD projectors, which are consisted of single or three LCD panels, the vertically polarized output of the projectors are rotated into the +45° and -45° orientations using half-wave retarder and then, linear polarizers are placed in front of the retarders at the desired directions of +45° and -45° as shown in Fig. 3. Here, also two circular polarizers(one is clockwise, the other is counterclockwise) with their axis at +/-45° can be also used instead of two linear polarizers.



(a) (b)

Fig. 3 Method of linearly polarized stereoscopic projection with Type-2 LCD projectors (a) Polarized outputs of Type-2 LCD (b) Half-wave retarders and linear polarizers

The output of the Type-3 projector is unpolarized, so that two linear polarizers are simply needed for polarized stereoscopic projection. As shown in Fig. 4, the linear polarizers at the output of the projectors are oriented at +/- 45° from the vertical axis.



(a) (b)

Fig. 4 Method of linearly polarized stereoscopic projection with Type-3 projectors(a) Unpolarized outputs of Type-3 (b) Linear polarizers

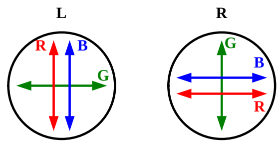
3. Proposed LCD Polarized Stereoscopic Projection System

Generally, it is well known that in the conventional projector configurations for polarized stereoscopic projection mentioned above, more than 50% of light energy might be inevitably lost in the process of polarizing the two projected views in the orthogonal directions. In particular light loss of these conventional polarized stereoscopic projection systems highly depends on the configuration of two projectors for polarized stereoscopic projection. A. Woods[1] discussed various configurations of the commercial projectors for polarized stereoscopic projection and evaluated their performances in terms of light loss. His experiments reveal that about 68%, 43%, 75% of light energy is measured to be lost for the cases of Type-1 LCD, Type-2 LCD and Type-3 projectors, respectively in the polarization process.

In case of Type-3 projectors, two polarizers must be placed in front of each projector for the two views to be polarized in the orthogonal directions, because the outputs of Type-3 projector are unpolarized, so that there can be no chance to get rid of the additional light loss caused by these polarizers in this system. On the other hand, in cases of Type-1 and Type-2 LCD projectors, their outputs are already polarized, so that a new LCD polarized stereoscopic projection system without using these additional polarizers can be devised by taking advantage of its output polarization property.

3.1 For the case of Type-1 LCD projector

A new configuration of Type-1 LCD projectors for polarized stereoscopic projection without polarizing filters is shown in Fig. 5. Figure 5(a) shows the left projector and it has output polarization of the normal Type-1 LCD projector, in which red and blue components of the projector are vertically polarized, whereas green component is horizontally polarized [5]. If the projector is physically rotated by 90° then, the red and blue components, which are originally polarized at the vertical directions, are converted into horizontal polarization, whereas the green component, which is originally polarized at the horizontal direction, is transformed into the vertical polarization as shown in Fig. 5(b).



(a) (b)

Fig. 5 Output polarization of the left and 90°-rotated right projectors for the case of Type-1 LCD (a) Left projector (b) 90°-rotated right projector

Thus, red and blue components of the left projector and green component of the 90°-rotated right projector are vertically polarized. At the same time, red and blue components of the 90°-rotated right projector and green component of the left projector are horizontally polarized. Accordingly, by simultaneously exchanging the green color components between the left and 90°-rotated right projectors through the signal processing technique, two full linearly polarized color sets, which should meet the requirements of color balance and orthogonal polarization can be obtained without a need of additional polarizing filters as shown in Fig. 6. That is, the left color set is vertically polarized, whereas the right one is horizontally polarized.

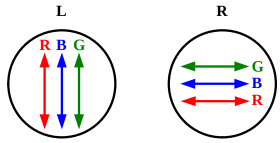


Fig. 6 Transformed output polarization of the left and 90°-rotated right projectors for the case of Type-1 LCD

Figure 7 shows a block-diagram of some steps of stereo image processing for Type-1 LCD projector-based polarized stereoscopic projection without using the polarizing filters.

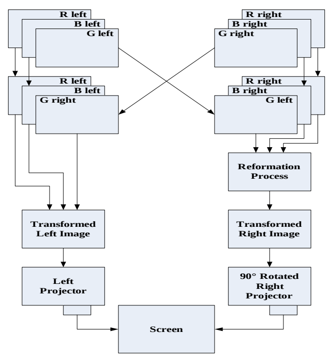


Fig. 7 Flowchart of stereo image processing for the case of Type-1 LCD projector

Firstly, the left and right video images captured by stereo camera are separated into three-color components of red, blue and green, respectively. Then, a new left image for the left projector, which is called a transformed left image here, is generated by mixing the red and blue components of the left image with the green component of the right image. At the same time, a new right image for the 90°-rotated right projector is generated by mixing the red and blue components of the right image with the green component of the left image. But, because the right projector has been initially rotated by 90° in respect to the left one in the proposed scheme, the right image projected the right projector is also rotated by 90° with respective to the left one. Therefore, the new right image must be adjusted in its orientation and aspect ratio to match with those of the left one through some image processing techniques before it is loaded into the 90 -rotated right projector, which is now called a transformed right image here.

These newly transformed left and right images are sent to the left and 90°-rotated right projectors, respectively and the size of the projected stereo image pair is matched on the screen by using the 3D reform function of the projector. Then, by using glasses with linear polarizers oriented at the horizontal(right eye) and vertical(left eye) directions, the newly transformed stereoscopic images can be finally viewed.

3.2 For the case of Type-2 LCD projector

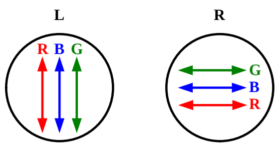


Fig. 8 Output polarization of the left and 90°-rotated right projectors for the case of Type-2 LCD

A new configuration of Type-2 LCD projectors for polarized stereoscopic projection without polarizing filters is shown in Fig. 8. Figure 8(a) shows the left projector and it has output polarization of the normal Type-2 LCD projector, in which all color components of LCD projector are vertically polarized. If the right projector is physically rotated by 90° with respect to the left one then, all color components of the projected right image, which are originally polarized at the vertical direction, are converted into the horizontal polarization as shown in the 90°-rotated right projector of Fig. 8. Thus, all color components of the left and the 90°-rotated right projectors are vertically and horizontally polarized, respectively. Accordingly, on the contrary to the case of Type-1 LCD projector, processes of color separation and exchange between the stereo video image are not needed any more in case of the Type-2 LCD projector, because two full linearly polarized color sets, which should meet the requirements for correct color balance and orthogonal polarization are already obtained just by rotating the right projector by 90° in respect to the left one as shown in Fig. 8. Here the left color set has vertical polarization, whereas the right one has horizontal polarization.

Figure 9 shows a block-diagram of some steps of stereo image processing for Type-2 LCD projector-based polarized stereoscopic projection without the use of polarizers. In case of Type-2 LCD projector, because the polarization directions of all color components are equal, color separation and exchange are not required. But, because the right projector has been initially rotated by 90° in respect to the left one, the right image projected from it is also rotated by 90° with respective to the left one, so that the new right image must be reformed in its orientation and aspect ratio to match with those of the left one through some image processing techniques before it is input to the 90°-rotated right projector just like the case of the Type-1 LCD projector.

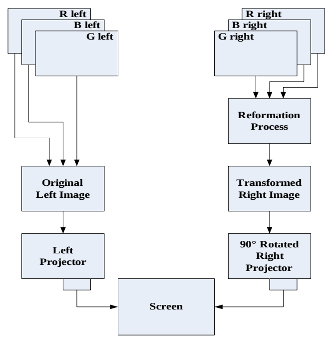


Fig. 9 Flowchart of stereo image processing for the case of Type-2 LCD projector

The original left image and the newly transformed right image are sent to the left and 90°-rotated right projectors, respectively and the size of the projected stereo image pair is also matched on the screen by using the 3D reform function of the projector. Then, by taking on same glasses used for the case of Type-1 LCD projector, we can observe the newly transformed stereoscopic images on the screen with a good quality.

4. Experiments and Discussions

In this paper, a new configuration of LCD polarized stereoscopic projection without polarizing filters is implemented by using the Type-1 LCD projectors, and its light efficiency is evaluated through some experiments. In the experiment, to capture the natural scenes from the real world in real-time, two IEEE 1394 cameras are employed as a stereo camera system, in which the two cameras are controlled to be geometrically on the epipolar line and the distance between the centers of the two cameras is kept to be about 65 mm. The camera model used in the experiment is Aplux C102T with a resolution of 640×480 pixels and a frame rate of 15 fps, which is set on RGB24 mode.

In addition, two NEC MT 1060R projectors belonging to the Type-1 LCD projector[6] are used for projecting the newly transformed stereo image pairs on the screen. This projector consists of three LCD panels each having a diagonal size of 1.0" and a resolution of 1024×768 pixels, and it also has a light output of 2600 ANSI lumens. A microgem-based Fresnel screen having a size of 80" is also employed, which can provide a wide viewing angle of 160° for both of the vertical and horizontal directions[7].

Figure 10 shows an experimental setup for performance evaluation of the proposed LCD polarized stereoscopic projection system using two NEC MT 1060R projector. As shown in Fig. 10, the left projector is normally placed, whereas the right projector is physically rotated by 90° with respect to the left one in the proposed scheme as explained above.

Fig. 10 Experimental setup for the proposed Type-1 LCD projection system

In the experiment, a sequence of stereo image pairs is captured by two IEEE 1394 cameras of Aplux C102T at a speed of 15 frames/sec. Initially, each of the right and left color images is separated into three-color components of red, green and blue. Then, red and blue components of the left image are mixed with the green component of the right image to create a transformed right image. At the same time, the red and blue components of the right image are mixed with the green component of the left image and then this image is rotated by 90° and resized in the aspect ratio from 3×4 to 4×3 to generate a transformed right image. Then, this newly transformed stereo image pair is sent to the corresponding right and left projectors, in which the left projector is normally placed, but the right projector is positioned to be rotated by 90° with respect to the left one. Accordingly, the transformed left image is projected to the screen through the normal left projector and the transformed right image is projected to the screen through the 90°-rotated right projector, and the sizes of the simultaneously projected stereo image pair are matched on the screen by using the 3D reform function of the NEC MT 1060R projector. Then, by using glasses with linear polarizers oriented at the horizontal and vertical directions, the newly transformed stereoscopic images can be finally viewed.

As explained above, all full color components of the projected left and right images are already polarized in the vertical and horizontal directions through physical rotation of the right projector by 90° and simultaneous exchange of the green component between them. Therefore, the polarization process of the two (right and left) projected images into the orthogonal directions with additional polarizers is not needed anymore in the proposed system. That is, while two polarizers employed in the conventional polarized stereoscopic system can be totally excluded in the proposed scheme, light efficiency of the projected light output can be maximized in the proposed system.

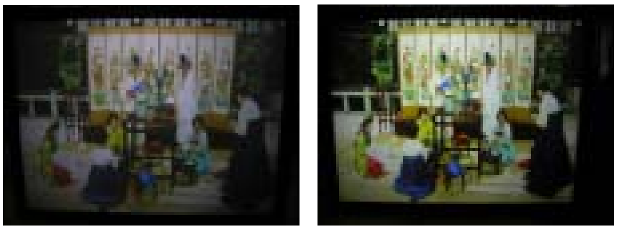
By putting on the glasses with linear polarizers oriented at the horizontal and vertical direction each other, the projected stereoscopic images can be viewed as a dramatically improved 3D image in brightness compared to those of the conventional systems.

Table 1 Relative comparison results of the measured light loss

Projector type	Measured light efficiency
(a) *Type-1 LCD*	~ 68 %
(b) *Type-2 LCD*	~ 43 %
(c) *Type-3*	~ 75 %
(d) Proposed method	~ 0 %

Table 1 shows comparison results for the light loss of the proposed and conventional polarized stereoscopic projection systems occurring in the polarization process, in which some data of the conventional systems are quoted from the experimental results performed by A. Wood[1].

As explained above, as the polarizing filters are taken away in the proposed LCD projection system, so that the light loss resulting from the polarizing filters could be reduced to zero percent, whereas in the conventional LCD projection systems, two polarizers are inserted in the polarization process and as a result, there could be some light loss. Table 1 reveals that the stereo image projected from the proposed system would be 213%, 75% and 300% brighter than those projected from the conventional Type-1 LCD projector-based, Type-2 LCD projector-based and Type-3 projector-based systems, respectively. Figure 11 shows experimental results for stereoscopic video images of 'Korean traditional wedding' projected on the screen from the conventional and proposed Type-1 LCD polarized stereoscopic projection systems, respectively. These figures also visually conform that output light projected from the proposed system is much brighter than that of the conventional system.



(a) (b)

Fig. 11 Experimental results of the Type-1 LCD-based polarized stereoscopic projection system (a) Conventional method (b) Proposed method

For example, a pair of NEC MT 1060R(2,600 ANSI lumens) projectors is considered for polarized stereoscopic projection, the conventional LCD polarized stereoscopic projection system employing two polarizers would produce a stereoscopic image about 1,664 ANSI lumens bright (2,600×32%×2), whereas the proposed system would produce a stereoscopic image about 5200 ANSI lumens bright (2,600×100%×2), so that a dramatic improvement up to 313% in light efficiency at the output stereoscopic image can be acquired in the proposed system.

Through these experimental results, the proposed scheme can be proved to have a maximum light efficiency in the polarization process compared to those of the conventional systems because the optical elements such as linear polarizers and waveplates are not included in the proposed system. Therefore, in this paper, a possibility of practical implementation of much brighter LCD polarized stereoscopic projection system with very low manufacturing cost is suggested.

5. Conclusions

In this paper, a new configuration of LCD projectors for polarized stereoscopic projection without having the external polarizing filters is suggested and experimentally tested. From some experimental results by using NEC MT 1060R projectors belonging to the Type-1 LCD projector, it is found that light efficiency of the proposed system can be maximized and the stereoscopic video image projected from the proposed system can be made to be 213%, 75% and 300% brighter than those projected from the conventional Type-1 LCD projector-based, Type-2 LCD projector-based and Type-3 projector-based systems, respectively.

6. Acknowledgements

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7. References

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