Novel Shutter Glass Control for Simultaneous Projection and Picture Acquisition

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Abstract. Virtual reality offers completely new possibilities for collaborative work over distributed environments. To enable collaborative work, it is necessary that both, virtual objects as well as the other users, can be seen simultaneously in real-time. A novel technique is necessary to overcome the contradiction of darkness and light for image projection and video acquisition, respectively. A stroboscopic light and a camera system are added to the existing VR-system and a few modification are made to existing shutter glasses. In such a solution, the method of projection in the VR-system remains unmodified. This paper describes how to resolve this contradiction with the constraint to make as few changes as possible to existing VR-systems. Furthermore the timing of the different devices is discussed.

1 Introduction

More and more VR installations are set up worldwide [1], [2]. Most of these installations are stand-alone, where the user is shown synthetic, computer-generated objects. Although present computing tools support information exchange and simple communication fairly well, collaboration on complex issues - be it models of functions, form or behavior - is not well supported. Current VR systems use projectors to display full-color, computer-generated stereoscopic images on the walls of a cube. Software synchronizes all the devices and calculates the correct perspective for each wall. In the CAVE [5]; [6] all perspectives are calculated from the user's point of view. Offset images are calculated for each eye to create the stereoscopic effect. The user can only experience this stereoscopic effect by wearing active stereo glasses, which alternately block the left and right eye.

Stand-alone installations lack the functionality for collaborative work among networked users and are thus not well suited for distributed teamwork. Most systems today do not allow interactions between multiple users and an object under design. In virtual meetings, humans are represented inadequately and disembodied through text, voice, or two-dimensional video projections. By integrating human representations in computer modeling environments, many of today's simulation techniques can be improved and new ones invented. Furthermore, the projects that use picture acquisition for rendering and gesture recognition not only face the problem of creating an effective team-working environment, but usually do not make use of a network [7];

[8]; [9]. In order to enable collaborative work in a distributed environment, a picture acquisition of the person must work together with the projection of both, the virtual objects and the other users, all in real-time [3], [4].

A new project called „blue-c" [10] proposes to build a system that achieves the following two major goals. The first goal is to enable a number of participants to interact in a virtual meeting and a collaborative setting, where the representation of people and objects is as complete as possible, in other words all objects and persons are fully rendered in three-dimensions with real-time movement and speech. The second goal is to provide an interaction between all the users and the simulated artifacts, be they models of function, form, behavior or their combination. The advantage of such simulations is the improvement of telepresence in conference meetings and the creation of immersive, virtual multi-user environments.

The key problem with simultaneous projection and picture acquisition is the illumination of the scene. On the one hand, to achieve a high quality image acquisition, a well-lighted scene is necessary. On the other hand, the projection system requires dark surroundings for a bright and sharp picture.

In order to overcome these conflicting lighting requirements, a new approach is used in the „blue-c"-project. The basic idea is to illuminate the „blue-c" actively with a stroboscopic light source during video image acquisition. The stroboscope is synchronized with the cameras, the projectors and the shutter glasses, that are needed to generate stereoscopic views in such VR Caves.

2 Contributions

In order to simultaneously provide a good projection and a good image acquisition, two different illumination phases are necessary. In a dark phase the spectator can watch the projection and in a light phase the camera can acquire the person’s texture.

Our approach uses a flash to illuminate the person in order to get the texture. During the flash, the spectators eyes are covered by a new, third phase of the shutter glasses, where the glasses become opaque. If the phase sequence is done fast enough, human perception fails to follow the oscillation from light to dark.

Thus, the basic idea of the presented concept is to make as few changes as possible to an existing technical setup. The projection system is the most critical part in a VR setup and so it should not be modified to accommodate the video acquisition. Furthermore, stereoscopic viewing should still be possible and not be affected by the stroboscopic illumination. These constraints lead to a solution shown in Figure 1.

The original two states of the shutter glasses are thus supplemented by a third state, which darkens both the left and the right lenses simultaneously. This dark phase is used to shield the user’s eye from the stroboscopic illumination. Each of the original states, one for the left and the other for the right eye, is shortened in order to create a third state. If this third state is kept very short, it will not be detected by the spectator’s eye. However, regardless of how short the new state is, the overall picture will appear slightly darker because of the decreased light integration (exposure) time for the left and the right eye. Consequently, the dark phase is made to be as short as possible. The actual value for the dark phase is constrained by the following aspects:

- the minimum required time (to grab a video frame) for a picture (dictated by the shutter speed)
- the maximum switching frequency of the shutter glasses
- the minimum time of the flash (including the afterglow time)
- the maximum rise time of the flash
- the latency time of the additional electronical circuitry

These constraints were verified by the preliminary, basic measurements.

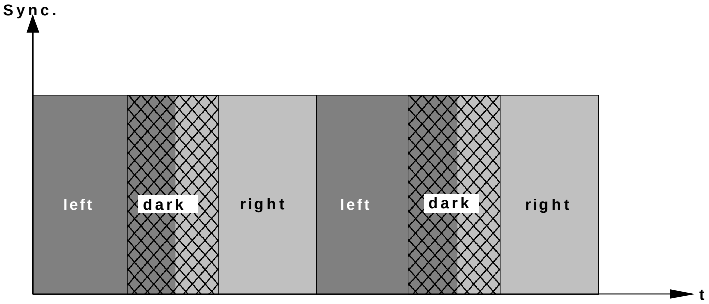

Figure 1 Time multiplexing diagram

3 Basic measurements

The shutter glasses and their triggering via the infrared link is the only part of the whole VR-system that has to be changed. Therefore, the following basic measurements have been made to verify that the requirements, listed in the above, can be fulfilled by the shutter glasses and the active illumination.

Shutter glasses (LCD): First of all, the time behavior of the glasses must be examined in order to get the maximum usable frequency and the shortest switching time from transparency to opacity. The measurement gave the following results:

- the LCD-shutters are fast enough to work on the required frequencies up to 60 Hz
- increasing the driving voltage has no effect on the opacity of the glasses
- it is possible to shorten the transparency phase of the glasses

Shutter glasses (electronic): In a next step the driving signals for the glasses itself have to be analyzed.

Figure 2 shows the two channels for the left and the right lens. The decoding and signal-processing unit within the shutter glasses generates a bipolar signal that is used to operate the LCD shutters. This bipolar signal is used to charge and discharge the LCD shutters since they behave like a capacitor. This implies that only the absolute value of the signal is used to darken the LCD shutters.

In order to use the already existing circuitry within the glasses that decodes the emitter’s infrared signals, an additional electronic circuit was added to delay the rising edge for the left eye impulse and to start the falling edge of the right eye impulse earlier. This modification of the pulse widths causes an overlap and thus creates the third, dark phase.

Active illumination: Next, a suitable stroboscopic illumination was chosen and it’s performance was measured. To provide such a high flash frequency only semiconductors or gas-filled light bulbs can be used. In the test setup a stroboscope and an array of white light emitting diodes (LEDs) were used. This illumination is bright enough to overpower the normal projection making changes to the projection system unnecessary.

The tests gave the following results:

- the stroboscope has sufficient light intensity.
- the pulse-width of the scope-flash is very small.
- active illumination using a stroboscopic light is very noisy.
- white light emitting diodes have lower intensity and need a wider pulse-width of the flash.

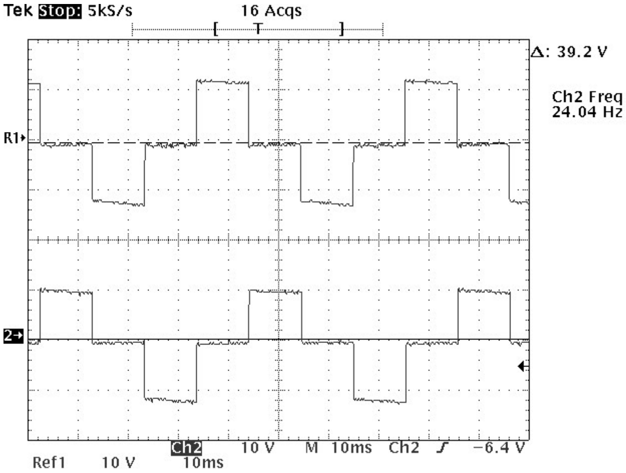

Figure 2 Driving signal for the glasses

4 Generating the third phase

For human perception, it is important that the new dark phase is symmetrical to the original phases for the left and the right eye. This must be taken into account when placing a third state into the operational cycle of the shutter glasses. In order to retain the system's symmetry, the third phase is placed during the transition from the original dark phase of the left eye to the dark phase of the right eye. Figure 3 shows the timing diagram of the prolonged signal for both glasses, compared to the original signal. In the chosen example, the picture refresh frequency is f_w = 60 Hz. Therefore, each eye will see 60 pictures per second and the dark phases for the left and the right eye can be calculated as:

$$T_D = T_L = 1/(2 * f_w) = 8{,}33 \text{ ms}$$

T_D = period of the dark phase
T_L = period of the light phase

In order to keep the symmetry, the frequency f_3 of the third phase must be either an integral multiple or an integral factor of fw. The following options are available for the period length T_3 of the dark phase:

$$f_3 = 2*n*f_w; \qquad 0 \le T_3 \le 1/(2*n*f_w); \qquad 1n = 1, 2, 3,... \qquad \text{(case 1)}$$

In case 1, the dark phase can be placed anywhere without distortion of the symmetry, since the third phase takes an equal amount of time from the right and the left eye.

$$f_3 = f_w; \qquad 0 \le T_3 \le 1/f_w \qquad \text{(case 2)}$$

In order to use the same amount of time from the left and the right eye in case 2, the dark phase must be placed symmetrically during the transition from the left to the right eye.

$$f_3 = f_w/n; \qquad 0 \le T_3 \le 1/f_w; \qquad n = 2, 3,... \qquad \text{(case 3)}$$

In case 3, the dark phase must be placed symmetrically during the change from the left to the right eye, as well.

Especialy case 3 was further examined. A higher frequency f3 did not give better results than case 2, because the person will still see the lower screen refresh frequency.

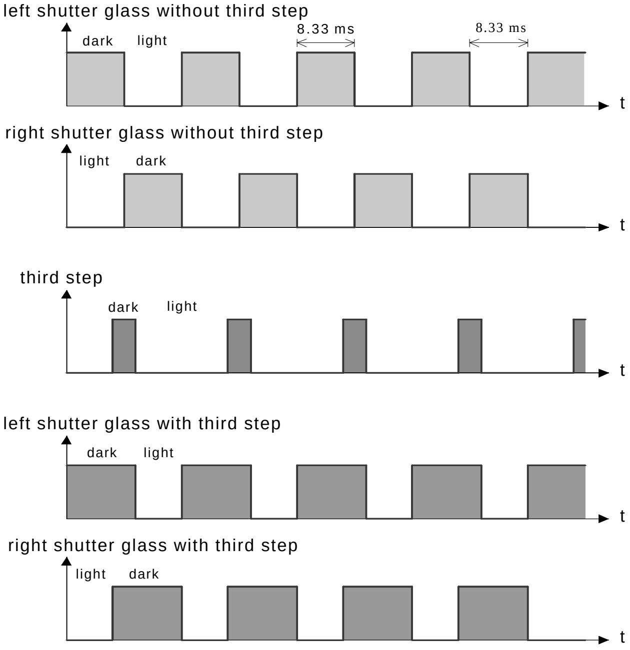

Figure 3 Signal diagrams for the shutter glasses

5 Modifications on the existing system

First experiments have been done with the CrystalEyes shutter glasses. This shutter glasses work with two LCDs. The additional circuit for the third phase is integrated between the original circuit of the shutter glasses and the two LCDs. Figure 4 shows the block diagram for this additional circuit.

The original bipolar signal coming from the shutter glasses is given to a rectifier stage since only unipolar signals will be processed. In the following, pulse-duration stage the rectified pulses are modified. The counter stage controls the number of pulses to be prolonged. This number can be chosen from one prolonged pulse within every period to one prolonged pulse only every 15th period. The third phase signal is combined with the original signals for the left and the right lens to generate the new signal for the glasses. Finally the signal passes to a flip-flop stage, which generates the bipolar signal.

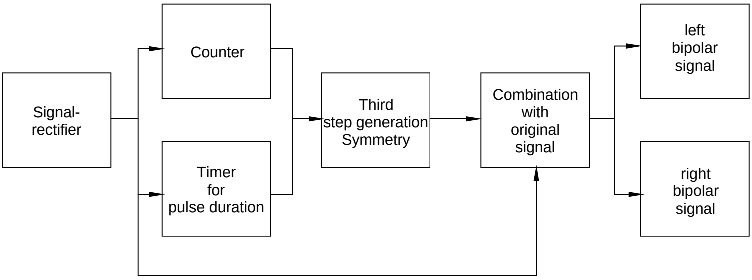

Figure 4 Block diagram for the additional circuit

Figure 5 shows the signal rectifier, the counter and the timer. Sig 1 is the signal coming in from the shutter glasses. The counter and the timer define when and how often the third phase is generated. The duration and the timing of the third state (the dark phase of the shutter glasses) are generated within this stage. The signal, sig 3, coming out of this stage corresponds to only a half of the third phase and will be completed in the following stage.

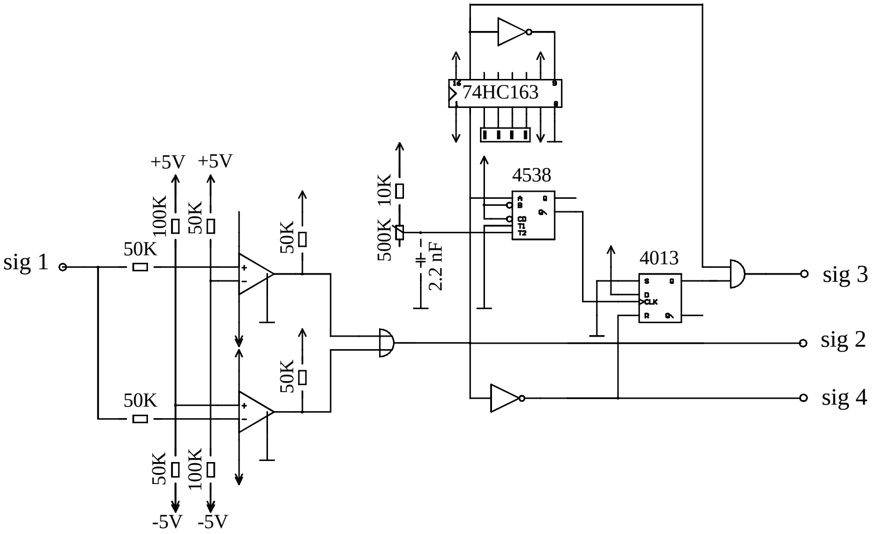

Figure 5 Signal rectifier**,** counter and timer

In the next stage, the symmetry of the third phase is generated. In Figure 6, signal sig 3 is coming in from the previous stage and sig 5 corresponds to the third phase.

To create the required symmetry, a capacitor is charged and discharged with a constant DC current. The input (sig 3) is at 0 V when charging the capacitor and at + 5 V when discharging the capacitor. The positive input of the first op-amp is regulated to 2.5 V. The capacitor is charged and discharged over the resistor that is connected to signal sig 3. A diode is connected in parallel to the capacitor to ensure that the op-amp does not saturate. In the last stage, the third phase signal sig 5 is combined with the original signals for the left and the right LCDs as shown in Figure 6 The new signals are then amplified. The alternation between positive and negative voltage prevents the LCDs from showing a memory effect. The LCDs for the left eye is connected to the signals sig 6 and sig 7 while the one for the right eye is connected to sig 8 and sig 9.

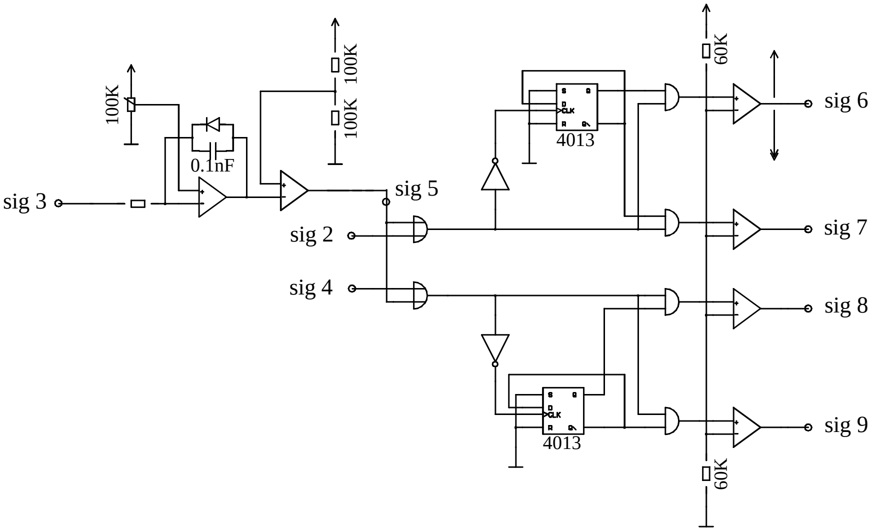

Figure 6 Symmetry generator of third phase and r output signal

6 Test setup

In order to verify the functionality the system, its components were assembled and integrated into a test setup as shown in Figure 7.

Figure 7 Test setup

The test setup is a chamber, which can be completely darkened. Inside the chamber, there is a monitor to provide a stereoscopic projection, combined with a standard infrared transmitter. The stereoscopic image can be viewed from outside through the modified shutter glasses, which are triggered via the infrared emitter. The chamber can be illuminated by stroboscopic light to illuminate the objects found inside. These objects can be acquired via a camera, which is installed in the chamber.

7 Experimental results

The chamber was used to test the feasibility of the whole system. The following points were of main interest:

- the subjective impression to the user
- the interference between the video image an the flash
- the need to synchronize the flash with the picture acquisition

In order to demonstrate the effectiveness of the modifications, the illumination of the object was viewed with and without a third phase. Figure 8 shows the difference between these two results.

Both images have been taken through the shutter glasses. In the left image, the shutter glasses were not modified, while in the right image the third phase was added. The illumination was the same for both images, i.e. the left object was illuminated with a flash while the right was illuminated with diffuse light.

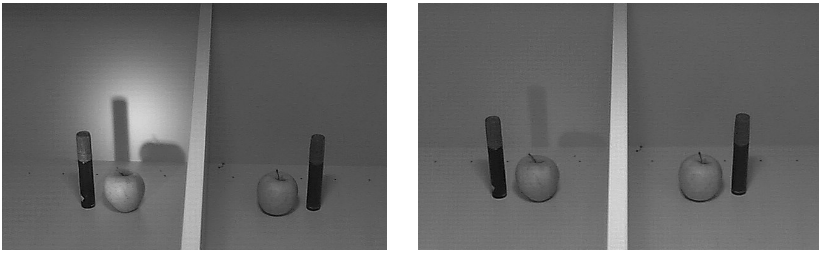

Figure 8 Illumination viewed without (left) and with the third phase (right)

Figure 8 shows that the flash illumination fades out almost completely. Tests with lower intensity flashes brought even better results in fading out the illumination. In both cases, the video image is bright enough to acquire good texture of the object.

Several tests were made in order to find out if the camera needs to be synchronized. A CCD-camera was installed within the test-setup of Figure 7. The camera was able to take video pictures every 1/50 s and was not synchronized with the stroboscopic flash, running at 48 Hz. Figure 9 shows typical results of such video acquisition.

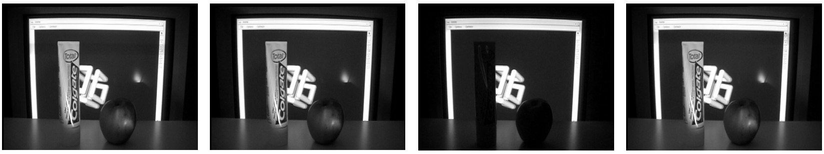

Figure 9 Typical video acquisition sequence with a CCD-camera and a stroboscopic flash

It can be seen from Figure 9 that there is one picture frame with poor illumination. This frame repeats after 0.5 s.

Figure 10 Typical video acquisition sequence with a CCD-camera and a LED flash

Using a LED's instead of the flash gives much better results. It can be seen from Figure 10, that the illumination differs. However, there is no picture frame without illumination.

The period of the flash is slightly longer than the period of picture acquisition. Assuming the flash illumination is a dirac impulse, there will be frames without illumination. The width of the stroboscopic flash is very similar to such a dirac impulse, while the LED illumination is not. This causes that every 25th picture appears dark when the stroboscopic flash is used. In order to avoid interference between the flash frequency and the picture frequency of the camera, the camera must be synchronized with the flash frequency.

This initial test set-up proved that the stroboscopic light could be used together with the video acquisition system. Furthermore, it has been shown that the third phase of the shutter glasses shields the user's eyes sufficiently from exposure to active scene illumination.

8 Conclusions

The basic measurements and the first test results from the setup proved that it is possible to integrate active illumination into a stereoscopic viewing system and perform texture acquisition of objects and people inside the system. A third phase (dark phase for both eyes) within the shutter glass protects the user's eyes from this additional illumination. The timing frequency of this third phase can be chosen to be fast enough so that the human eye cannot resolve it.

The new technology is compatible with existing VR-systems and incurs low additional costs from the modified shutter glasses.

This basic technology will allow the development of new applications of virtual reality within a collaborative framework.

9 Future work

In addition to the small test chamber, the system needs to be tested within a full-size test setup. This will give the user a better impression of a modified VR-system.

The tests have shown that the stroboscopic illumination is needed at every display cycle. Therefore the counter in the electronic circuit is no longer necessary.

Further work will also be focused on the stroboscopic illumination. The stroboscope used in the initial set-up was very noisy; a semiconductor flash could be used instead. This semiconductor flash can be made from a number of LED's placed all over the projection room. This will create sufficiently diffuse light, as required.

In addition we will work on an illumination with infrared light, that can be used in parallel to the projection and the active illumination. The infrared light together with specialized cameras will allow an easy silhouette extraction of the person inside the system.

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