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A3_8 Two mirrors and infinity. II

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Abstract
We extend the work presented in "A3_7 Two mirrors and infinity" to analyse the potential of the system to cause detectable time delay, caused by the finite speed of light. It was found that with the setup, considered in the aforementioned paper, it is impossible for a human eye to perceive such a difference. In turn, it was found that a commercially available high speed video camera could theoretically detect such image changes.

Introduction

The article [1] considered two parallel mirrors facing towards each other, with an observer and a light source situated at the midpoint between then and at distance s from each other. In this setup the observer would view a series of images of the light source. It was found what an average observer would be able to perceive approximately 83 images, provided that the light source is a typical domestic light bulb, and that the distance between the mirrors, as well as distance between the observer and source, is 2 metres.

In this article we focus our attention primarily on light time delays. In particular we are interested in detecting this time delay either with eyes, or with a high speed video camera.

Human eyes

The model is as described in [1]. We keep the parameters at same values.

If we can initiate an instantaneous stop of the light source emittance, the observer, if equipped with high frame rate, will see the images disappearing, starting from rank k = 0 and ending with highest detectable rank k_{max}.

For the observer to notice the time delay, their field of view should include the image with shortest travel time k_{min} = 0, as well as the image with the longest travel time k_{max}.

Using equation of constant speed, and equation (2) from [1], we may find the travelling time difference:

$$t_{diff} = t(k_{max}) - t(k_{min})$$

$$t_{diff} = \frac{1}{c}\left(\sqrt{4a^2 {k_{max}}^2 + s^2} - \sqrt{a^2 + s^2}\right), \qquad (1)$$

where c is the speed of light (in vacuum) taken as 3×10^8 m/s, and a and s are as defined in [1].

For the setup described in [1] and k_{max} = 83, t_{diff} = 1×10^{-6} s.

Human eye can detect substantial image changes at a rate of approximately 40 Hz [2]. This corresponds to 25000×10^{-6} s intervals. Thus human eye will not detect a difference between these image changes.

We can in turn estimate the minimum number of perceivable images, needed to detect a time delay. Rearranging equation (1) for k_{max} and using t_{diff} = 25000×10^{-6}, yields $k_{max} \approx 1.9 \times 10^6$.

Using equation (4) from [1] the initial output power of the light source will need to be ≈ 10^{164} W.

High speed video cameras

Video cameras are usually designed to mimic the colour/intensity perception of human eyes, so we can safely assume that a rank of 83 shall also describe the image with lowest intensity detectable in this experiment. Therefore, for 1×10^{-6} s, as calculated above, the camera should be rated at least 1×10^6 frames per second (fps).

There are commercially available cameras, which are rated 1 million fps [3] and such cameras would theoretically just be able to detect the time difference.

Conclusion

It was clearly shown that human eyes cannot detect a difference in time between disappearances of images in the mirror with the aforementioned setup. This difference will be noticed only if approximately 1.6 million of images are perceivable. At such high density of images they will not be resolvable by human eye. Moreover, to make images perceivable up to this rank, the power of the light source should be of the order of 10^{164} W, which is perhaps larger than the luminosity of the Universe.

In turn, high speed cameras, which are available today, are estimated to have high enough fps rating to detect the time delay image rank of 83, caused by the finite speed of light.

Bibliography:
[1] Karazhov et al., *A3_7 Two mirrors and infinity* (2011), The Journal, Vol. 9, pp. 1 - 2.
[2] http://webvision.med.utah.edu/temporal.html#flicker (Accessed: 2/3/11)
[3] http://www.olympus-ims.com/en/hsv-products/i-speed-fs/ (Accessed: 2/3/11)