Mathematic Formulae for Calculating the CAVE's Room Size

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Abstract. This paper is focused on the creation of mathematic formulae for calculating the room's size where a CAVE (CAVE Automatic Virtual Environment) of specific dimensions will be built. Furthermore, the design of mathematic formulae for computing the CAVE's size, when the room's size is already established. Four designs are explained. In the first design, the CAVE's walls are parallel to the room's walls. In the second design, the CAVE's walls are oblique to the room's walls. In the third design, the mirror and projector technique is used. Finally, the mirror and projector technique is used, too. The only difference is that the projectors are set on a strategic place.

Keywords: CAVE, projection, immersion.

1 Introduction

A CAVE is a system based on multiple projection' s screens that surround the viewer, in which projectors are directed to four, five or six of the walls of a room-sized cube and where generally a virtual environment is used.

The first CAVE was originally developed at the Electronic Visualization Laboratory at the University of Illinois at Chicago in 1992 [1], [2]. This CAVE used the mirror and projector technique.

Actually, this technique is used for many CAVEs, as in [3], [4] and [5]. Nevertheless, there is no reference that indicates a specific method for computing the minimum space required for building a CAVE. There are no references that may help us to compute the physical space when the mirrors are used in different positions.

2 Projection

In this research, different projectors were used for measuring the projected image's size. The results were similar. Every projector had an aspect ratio 4:3. The projector's length was not taken in account due to it is minimum size.

Fig. 1 shows the maximum projection's size, when the distance between the projector and the wall is of 3m, it is possible to notice that the width of the projected image is almost half of the distance between the projector and the wall. For this

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reason, in the rest of this paper the projection's width will be taken as half of the distance between the projector and the wall.

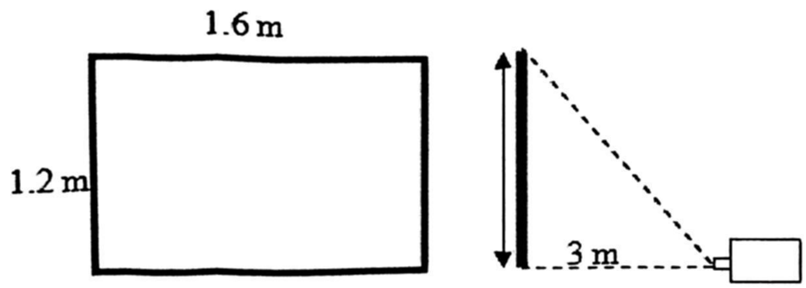

Fig. 1. Image's size obtained at a distance of 3 m.

3 Room Size

In order to achieve a good immersion level within the CAVE, its walls must be taller than the average height, so that people may not have the opportunity of looking over them. Using a screen of 2.10 m. height should be enough for most situations.

Considering the aspect ratio of 4:3, means that the projection height is 75% of its width [6], this example sets the screen width as P = 2.80 m. In this paper we use P, which avoids loss of generality.

3.1 Room Design #1

The first one is a straight approach that allows us to set the projectors behind screens. See Fig. 2.

$$W\_1 = 5P. \tag{1}$$

$$W\_2 = 3P. \tag{2}$$

$$R\_1 = (5P)(3P) = 15P^2. \tag{3}$$

This means that the room's width must be of at least 5P, while its length must be larger than $3P$ to allow the user's entrance into the cave.

In our example, where P = 2.80 m., the room size should be: R_1=117m^2.

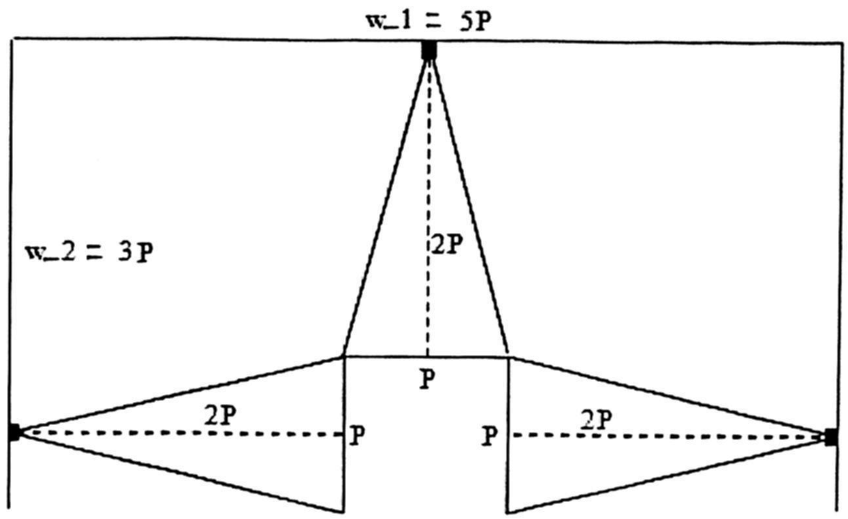

Fig. 2. Room size: CAVE walls parallel to room walls.

3.2 Room Design #2

In order to reduce the room's size, we can set the projectors at strategic places of the room. Corners may be used.

Fig. 3 shows that the distance from the center point of the room to any corner is: $\frac{5P}{2}$. Therefore the length of each wall is: $W=\frac{5P\sqrt{2}}{2}$.

$$R\_2=\left(\frac{5P\sqrt{2}}{2}\right)\left(\frac{5P\sqrt{2}}{2}\right)=\frac{25P^2}{2}. \quad (4)$$

Using P=2.80 m., the room's size is $R\_2=98m^2$

3.3 Room Design #3

As it was mentioned before, the projection's size depends on the distance between the projector and the wall, thus note that it is possible to reduce the room's size requirements by using mirrors.

There are two types of mirrors that are useful for back-projection systems such as: foil mirrors and surface glass mirrors. Normal mirrors are not usually used because they may produce double images [5].

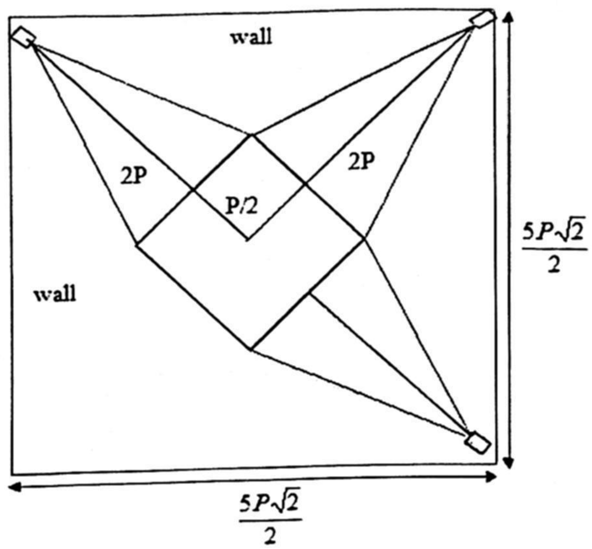

Fig. 3. Shows the room's size with the projectors placed in the corners.

Fig. 4 shows an example of an image's size obtained with a projector and a mirror. The strategy is to set the projector near the screen. The projection is sent to the mirror and the mirror reflects the projection onto the screen. The projection's distance and the horizontal projection's size are both equal to P.

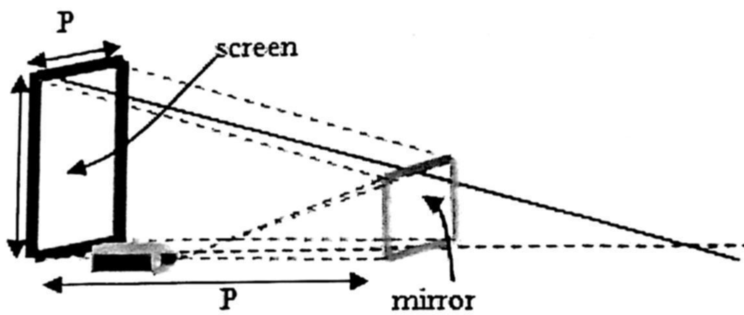

Fig. 4 A larger image size is obtained in smaller sized rooms using mirrors.

Fig. 5 allows us to see that the distance from the center point of the room to any corner is: $\frac{7P}{4}$, for that reason, the length of each wall is: $\frac{7P\sqrt{2}}{4}$.
In this design, the mirror's size is half the screens' size.

$$R\_3 = \left(7P\frac{\sqrt{2}}{4}\right)\left(7P\frac{\sqrt{2}}{4}\right) = \frac{49P^2}{8}. \quad (5)$$

It is necessary to be careful to place the mirror in the correct position because it is possible that the projection crosses a screen

In our example, where P = 2.80m., the room's size should be R_3= 48.02m^2

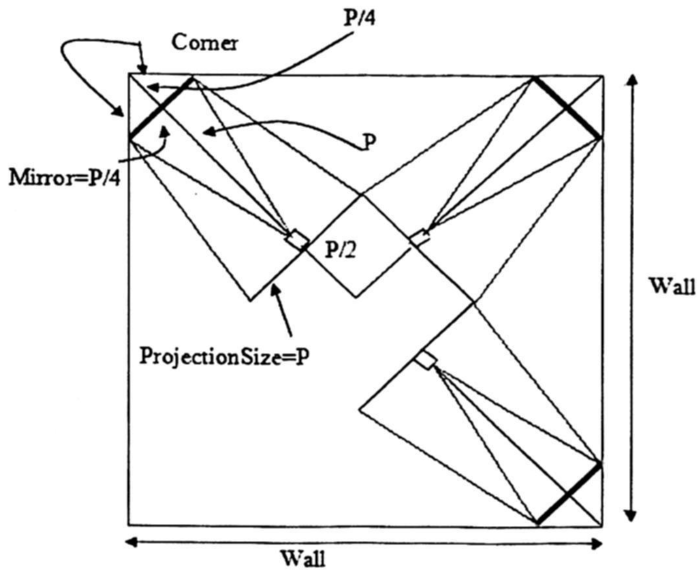

Fig. 5. Room size using mirrors.

3.4 Room Design #4

It is possible to find strategies for taking advantage of the mirrors. Fig. 6 shows that the mirror can be inclined towards the projector.

Fig. 7 allows us to see that the distance from the center point of the room to any corner is approximately $\frac{3P}{2}$, therefore the length of each wall is $\approx \frac{3P\sqrt{2}}{2}$

$$R\_4 \approx \left(3P\frac{\sqrt{2}}{2}\right)\left(3P\frac{\sqrt{2}}{2}\right) \approx \frac{9P^2}{2}. \quad (6)$$

In our example, where P = 2.80m., the room's size should be of $\approx$35.28m^2.

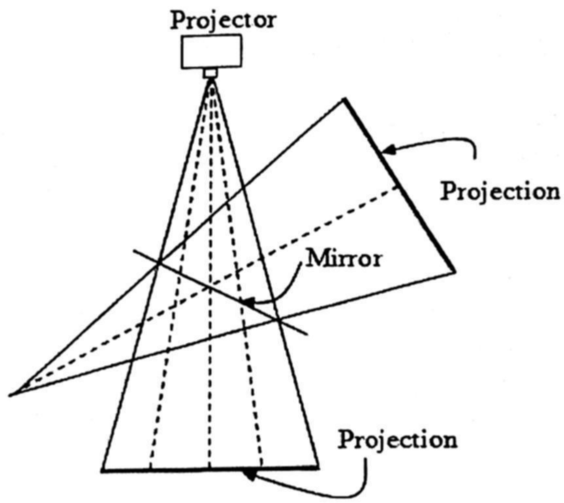

Fig. 6 Projection using an inclined mirror.

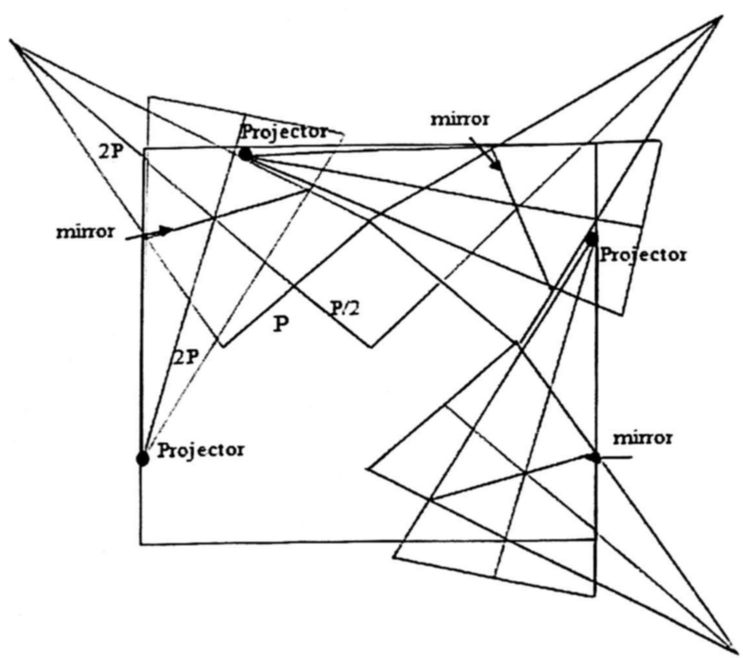

Fig. 7. Room Size using the mirror and projector technique, the CAVE's walls are in an oblique position against the room walls, placing the projectors in a strategic place

4 Calculating the CAVE's Size when the Room's Size is already Established

In the designs shown above, the room's size depends on the screen's size. Therefore, it is possible to calculate the CAVE's size when the room's size is known.

The CAVEs' sizes (C_2, C_3 and C_4) are calculated taking as a reference designs 2, 3 and 4:

If we know the room's size, we can calculate the CAVE's dimensions. Where P is the width and depth, ¾P is the height (H).

For design #2 and taking as reference formula (4), we can calculate C_2.

$$P = \frac{\sqrt{2}}{5} W . \tag{7}$$

$$H = \frac{3\sqrt{2}}{20} W . \tag{8}$$

$$C\_2 = \left(\frac{\sqrt{2}}{5} W \right) \left(\frac{3\sqrt{2}}{20} W \right) \left(\frac{\sqrt{2}}{5} W \right) . \tag{9}$$

For design #3 and taking as a reference formula (5), we can calculate C_3.

$$P = \frac{2\sqrt{2}}{7} W . \tag{10}$$

$$H = \frac{3\sqrt{2}}{14} W . \tag{11}$$

$$C\_3 = \left(\frac{2\sqrt{2}}{7} W \right) \left(\frac{3\sqrt{2}}{14} W \right) \left(\frac{2\sqrt{2}}{7} W \right) . \tag{12}$$

Finally, for design #4 and taking as a reference formula (6). we can calculate C_4.

$$P = \frac{\sqrt{2}}{3} W . \tag{13}$$

$$H = \frac{\sqrt{2}}{4} W . \tag{14}$$

$$C\_4 = \left(\frac{\sqrt{2}}{3} W \right) \left(\frac{\sqrt{2}}{4} W \right) \left(\frac{\sqrt{2}}{3} W \right) . \tag{15}$$

5 Conclusion

Four designs for building a CAVE with different characteristics were explained in this paper. Each design was evaluated with different projectors and the results were satisfactory.

Two contributions were given:

-The creation of mathematic formulae for calculating the room's size where a CAVE of specific dimensions would be built.

- The creation of mathematic formulae for calculating the CAVE's size when the room's size is already established.

Designs #1 and #2 used a great amount of space. Design #3 used the mirror and projector technique; the space used in this design was reduced. In my personal opinion, the best option was the last one.

With these designs we can demonstrate, that the technique of mirrors and projectors is effective.

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