Characteristics of Viewing Zone in Multiview 3 Dimensional Imaging Systems

Jung-Young Son
Div. of Electronics and Electrical Engineering, Han-Yang University, Seoul, Korea
Vladmir V. Saveljev[1]
Div. of Electronics and Electrical Engineering, Han-Yang University, Seoul, Korea

Abstract
In contact-type multiview 3 dimensional imaging systems, the optimum design parameters are not easily found because of difficulty in determining the size of viewing zone. Two factors related with the viewing zone, such as different view image patching and the widths of the viewing regions are discussed to explain the difficulty.

1. Introduction

In 3 dimensional(3-D) imaging systems without using eyeglasses, viewing zone is an essential parameter to be designed first. The viewing zone enables viewers to perceive 3-D image from the multiview images displayed on a screen/display panel. Hence it is desired to maximize the zone for more simultaneous viewers. The viewing zone forming principle is different for different types of 3-D imaging systems. In the projection type 3-D imaging systems, the viewing zone is defined simply as the image of the exit pupil of projectors. To increase the viewing zone size, it is necessary to increase the number of projectors. In the contact type, the zone is defined as a spatial volume that has the magnified dimension of a pixel cell shape, as its cross-section[1]. Since the pixel cell is composed of the same number pixel from the different view images, which is aligned as the multiview camera array that provides the different view images, the gathering of the pixels of a view image from the pixel cells with different pixel number geometrically divides the viewing zone into many different sub-regions[2]. Images seen at these sub-regions have different image qualities, because different number of different view images are appearing in different sections of the image appearing in the display panel and seen simultaneously at different sub-regions, i.e., different view images are patched together to make a full image on the panel. This will induce that no 3-D image can be perceived at certain sub-regions. As a result, the viewing zone size will be limited. The viewing zone size is also limited by this image patching because the image quality can be reduced by this patching, i.e. The viewing zone size is also affected by the multiview image arrangement in the image display panel. In this paper, the size of viewing zone is related with different view image patching and multiview image arrangement methods.

2. The Relationship between Pixel Cell and Viewing Zone

In contact-type multiview 3-D image systems, the multiview images are aligned in the display panel as pixel cell units. Each pixel cell is consisted of the same number pixels from different view images to be displayed. Each pixel in the cell is aligned the same order as the multiview camera arrangement. The cell can have any shape if the components of viewing zone forming optics such as lenticular and microlens arrays and cross lenticula arrays, can be made the same as the cell and aligned the same as the cell arrangement in the panel. Furthermore, the cell should be aligned without any gap with its neighbors and with no direction change as shown in Fig. 1. If there is a gap between each pixel cell, it creates a gap between each viewing zone. Many possible shapes of pixel cells for full parallax image generation, shown in Fig. 1 tell that the cells can be easily designed, so does the viewing zone. For the case of horizontal parallax only image display, the pixel cells have a shape of vertical or slanted vertical column. All pixel cells in the panel should have the same shape, size and direction. Since the viewing zone cross-section has the same shape as the cell, the proper selection of the cell shape is important to minimize the pseudoscopic effects[3] and maximize the viewing zone size.

In the contact–type systems, many viewing zones are created because each optical component of optical plates used for viewing zone forming can form images of pixel cells which are not directly underneath it. The viewing zone cross-section of the viewing zones are joined together to make a single plane cross-section without overlapping. However, these joined cross-sections have less brightness than the one in the center which is created by the cell underneath the component. Due to this brightness reduction, only few extra viewing zones can be created at both left and right sides of the central one. This is shown in Figs. 2 and 3 for the pixel cells with a square and diamond shape, respectively. The pseudoscopic regions appear along the boundary of each viewing zone because viewer's two eyes are different viewing zones. For the case of the rectangular or square pixel cell, the positions of the pseudoscopic regions do not change with lowering or heightening the viewer's eyes. However, for the diamond case, the positions are changing with the height change. This means that the pseudoscopic region can be easily avoided for the latter by changing viewer eye positions slightly. Hence the diamond shape pixel cell effectively mitigates the pseudoscopic effects.

3. Viewing Zone Boundary Defined by Different View Image Patching

The viewing zone forming geometry in contact-type 3-D imaging systems is somewhat complicate because pixels composing a specific view image are distributed every pixel cells in the display panel. The plane view of viewing zone forming geometry in contact-type 3-D imaging systems is shown in Fig. 4 for both bigger(Fig. 4(a)) and smaller (Fig. 4(b)) viewing zone cross-section than the display panel. The number of different view images to be displayed is 4 for Fig. 4(a) and 5 for Fig. 4(b), and the viewing zones considered are 3 for both cases. In Fig. 4, the segments with number 1 represent the regions where only a single view image can be seen through entire display panel. The segments with numbers other than 1, represent the regions where different view images are partly patched to compose a full panel image as shown in Fig. 5. The numbers represents the number of different view images patched together. For the case of full parallax image, the vertical direction of the image will also be patched with different view images.

Fig. 4 shows some interesting facts: 1) The total number of different view images to be patched together is the same as the number of multiview images to be displayed. 2) The viewing regions in each viewing zone provides images patched in the order of increasing view numbers such (1,2), (2,3), (3,4), (4,5), (1,2,3), (2,3,4), (3,4,5), (1,2,3,4), (2,3,4,5) and so on. 3) Zones between two neighboring viewing zones also work as viewing zone. Each viewing regions in this viewing zone provide images patched in the order of (5,1), (4,5,1), (5,1,2), (3,4,5,1), (4,5,1,2), (5,1,2,3), (2,3,4,5,1), (3,4,5,1,2), (4,5,1,2,3) and (5,1,2,3,4). 4) When viewing zone cross-section is more than the width of the display panel(Fig. 4(a)), high numbered viewing regions are not closed. This means that the viewing zone can be extended to very long distance from the panel. 5) The regions further away from the numbered regions can also be worked as viewing zone if the patched image can still make viewers perceived 3-D image. In these regions, the different view images are patched such as (1,2,3,4,5,1) ·····(5,1,2,3,4,5), (1,2,3,4,5,1,2) ·····(5,1,2,3,4,5,1) and so on. As further away from the display panel or closer to the panel, the same view images are repeated many times. For the case of the full parallax image, the same image patching appears in the vertical direction too. These facts indicate that viewing zones can occupy almost entire space in front of the display panel unless the patched images do not deteriorate the 3-D image quality. It is not known that how many different view images can be patched together for 3-D images with reasonable quality. Of course, the number depends on the disparity differences between neighboring view images. To increase the viewing zone size, the disparity differences between different view images should be minimized. However, in this case, image depth can be sacrificed. The entire viewing zone will be eventually limited by the different view image patching. Another limiting factor of the viewing zone is the width of each viewing region. As shown in Fig. 4, the widths of viewing regions are increasing as away from the panel. If these widths become more than our interocular distance, viewers can find difficulty in locating their two eyes to see different view images to perceive 3-D images. To make these widths smaller, the width of the viewing zone cross-section needs to be less than the length defined by our interocular distance multiplied by total different view numbers to be displayed. In any case, the entire viewing zone will be limited by the increase in the width of the viewing regions. So it is difficult to draw the boundary of entire viewing zone. It should be defined by the Human factor consideration because the degrees of the stereoscopic effect and image sharpness perceived by viewers are different for different persons[4]. Once this value is defined, optimum design parameters[5] for contact type 3 dimensional multiview imaging systems, such as viewing zone size, total number of different view image to be displayed, the width of viewing regions marked with number 1, disparity differences between different view images and so on can be determined. When the image patching and the width of viewing regions are not considered and the panel size is bigger than the length of the viewing zone cross-section, the geometrically defined viewing zone extension is defined by $\underline{PWD/(P^2 - W^2)}$, where $\underline{P}$ is the panel width, $\underline{W}$ length of viewing zone cross-section and $\underline{D}$ distance between the panel and the viewing zone cross-section. This relationship tells that viewing zone extension increases with increasing $\underline{W}$ and $\underline{D}$. However, increasing $\underline{P}$ actually reduces the viewing zone extension. Since the viewing zone area is proportional to $\underline{PW^2D/(P^2 - W^2)}$, the longer view zone cross-section results the wider viewing zone size. Since increasing $\underline{D}$ requires bigger $\underline{P}$, this increasing may not result any real increase in viewing zone size. It is also noticed that as the viewing zone cross-section increases, the more different view images are required. This means that the image patching plays a critical role of limiting the viewing zone size.

4.Effects of Pixel Cell Shape on Viewing Zone Size

Since the viewing zone cross-section is the magnified image of the pixel cell, the viewing zone size is one way or the other related with the pixel cell shape. However, it s effect will be much smaller than the image patching.

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Fig.1. Various Possible Pixel Cell Shapes

Fig. 2. Viewing Zone Cross-section with a Square Shape

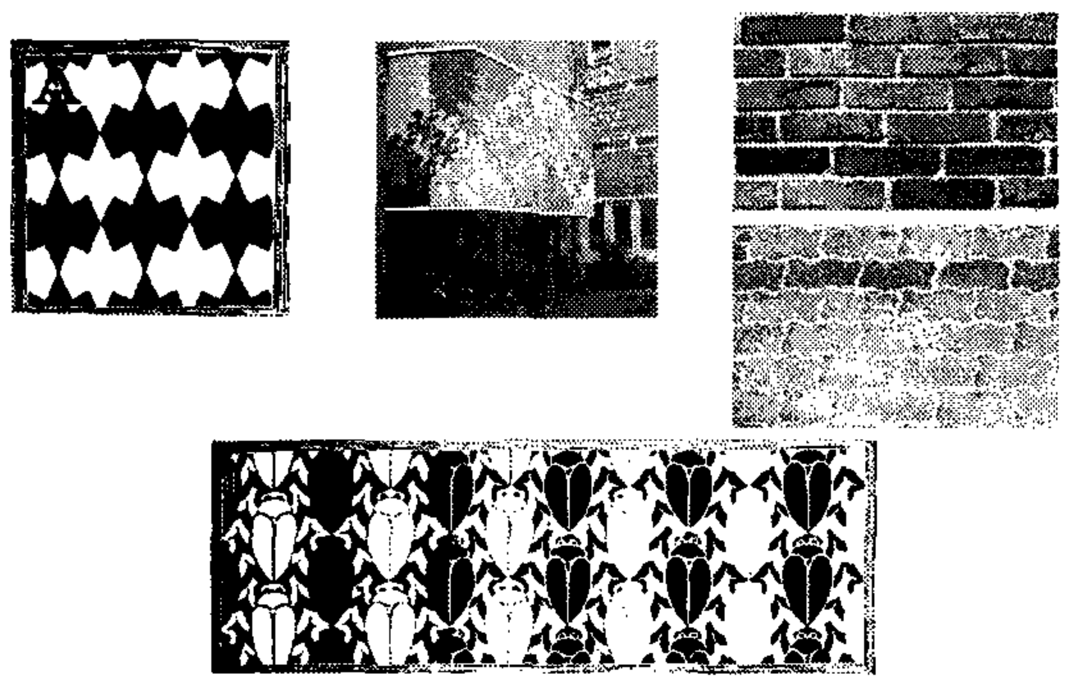
Fig. 3. Viewing Zone Cross-Section with a Diamond Shape

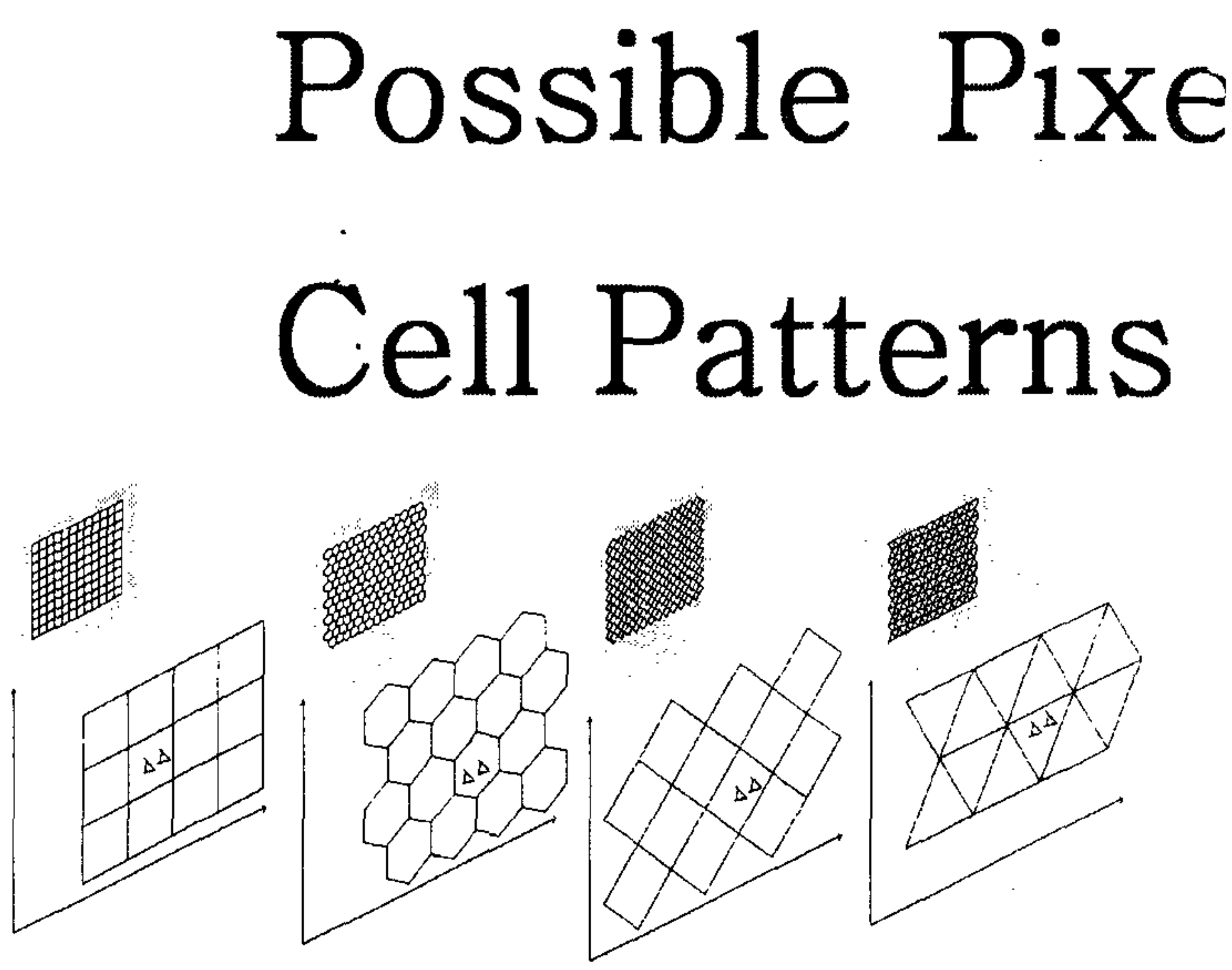
Fig.4. Viewing Zone Forming Geometry

(a) Panel Size < Viewing Zone Cross-Section

(b) Panel Size > Viewing Zone Cross-Section

Fig. 5. An Example of Different View Image Patching.





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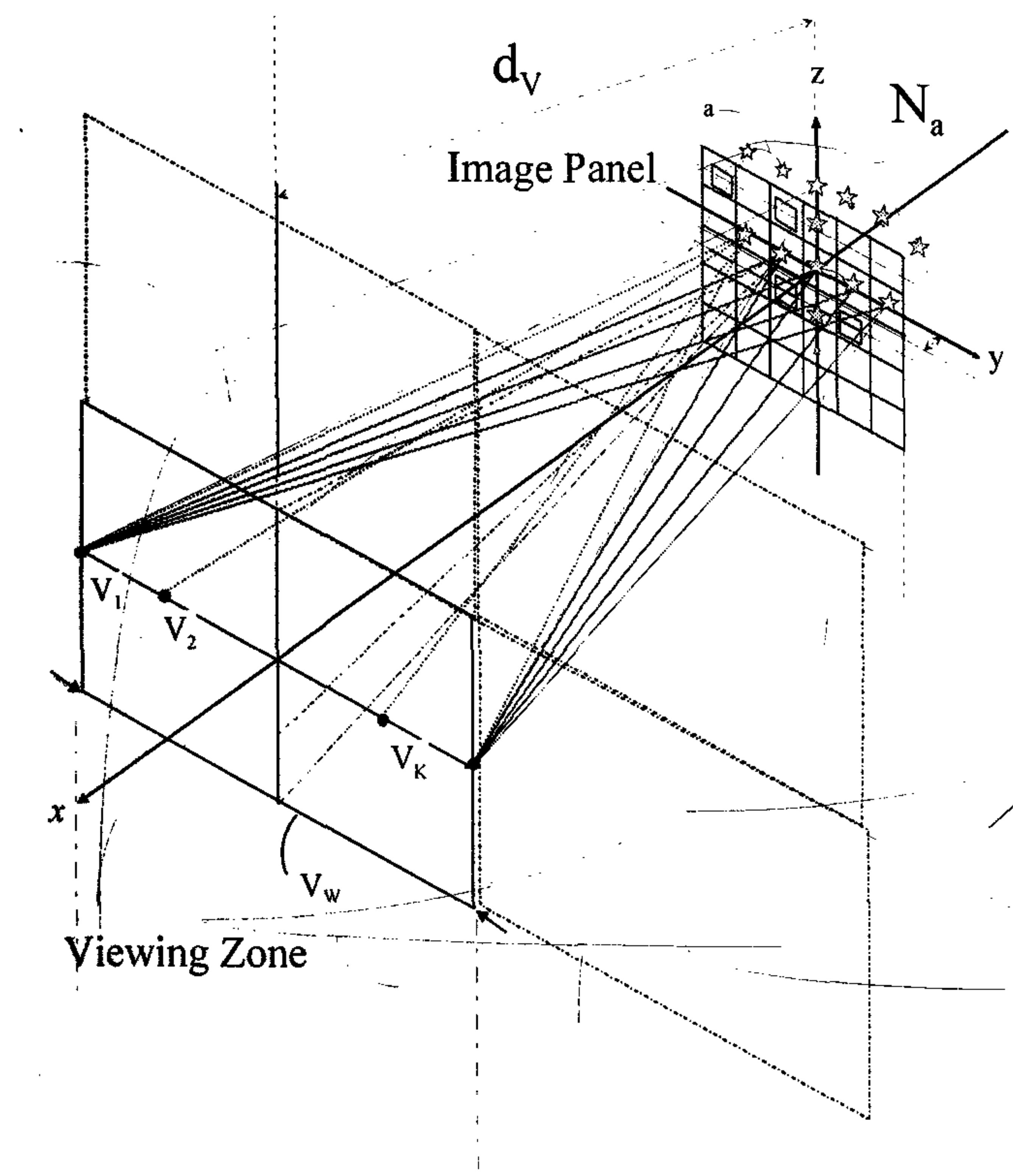

Fig. 2. Viewing Zone Cross-section with a Square Shape

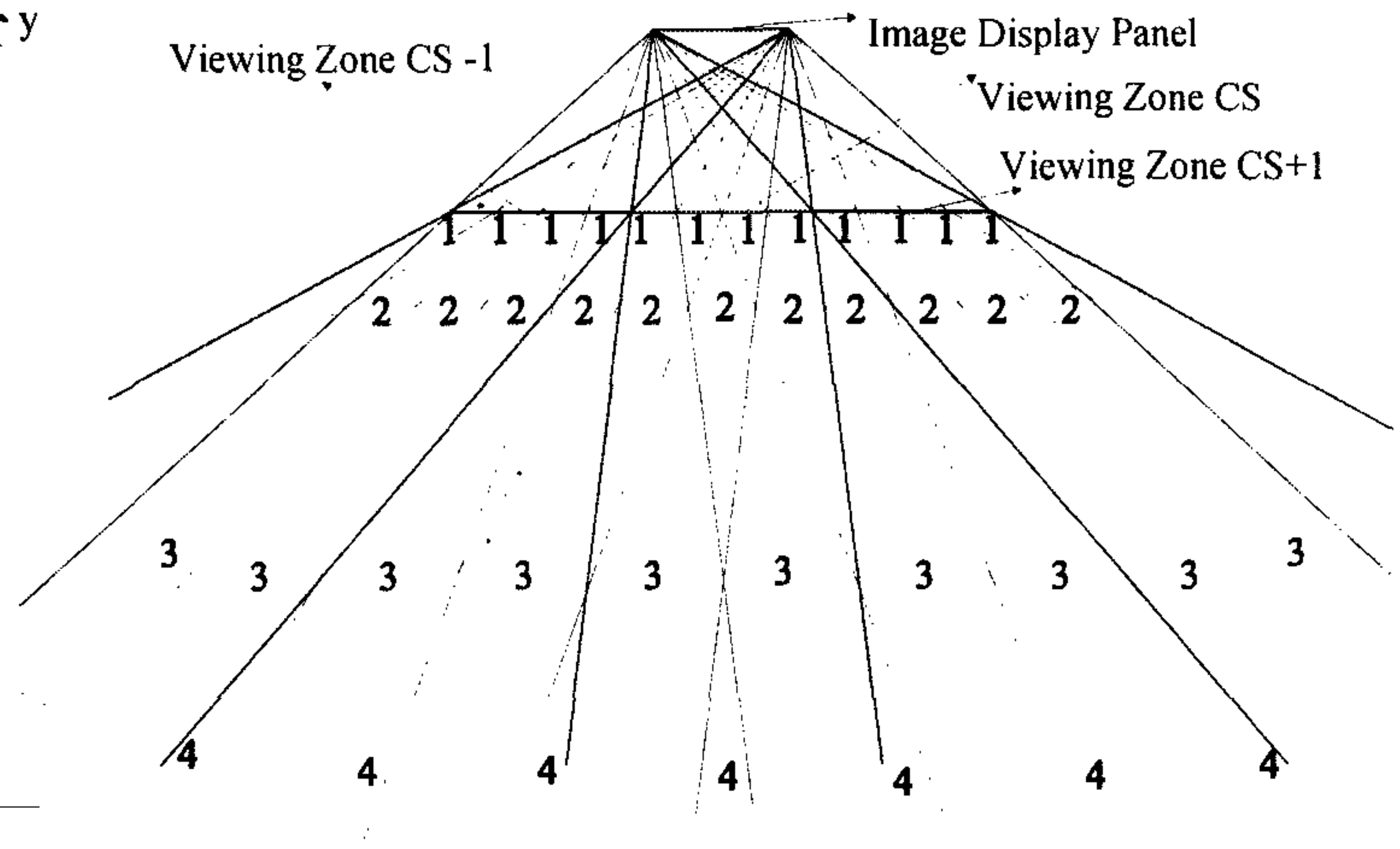

Fig.4. Viewing Zone Forming Geometry
(a) Panel Size < Viewing Zone Cross-Section

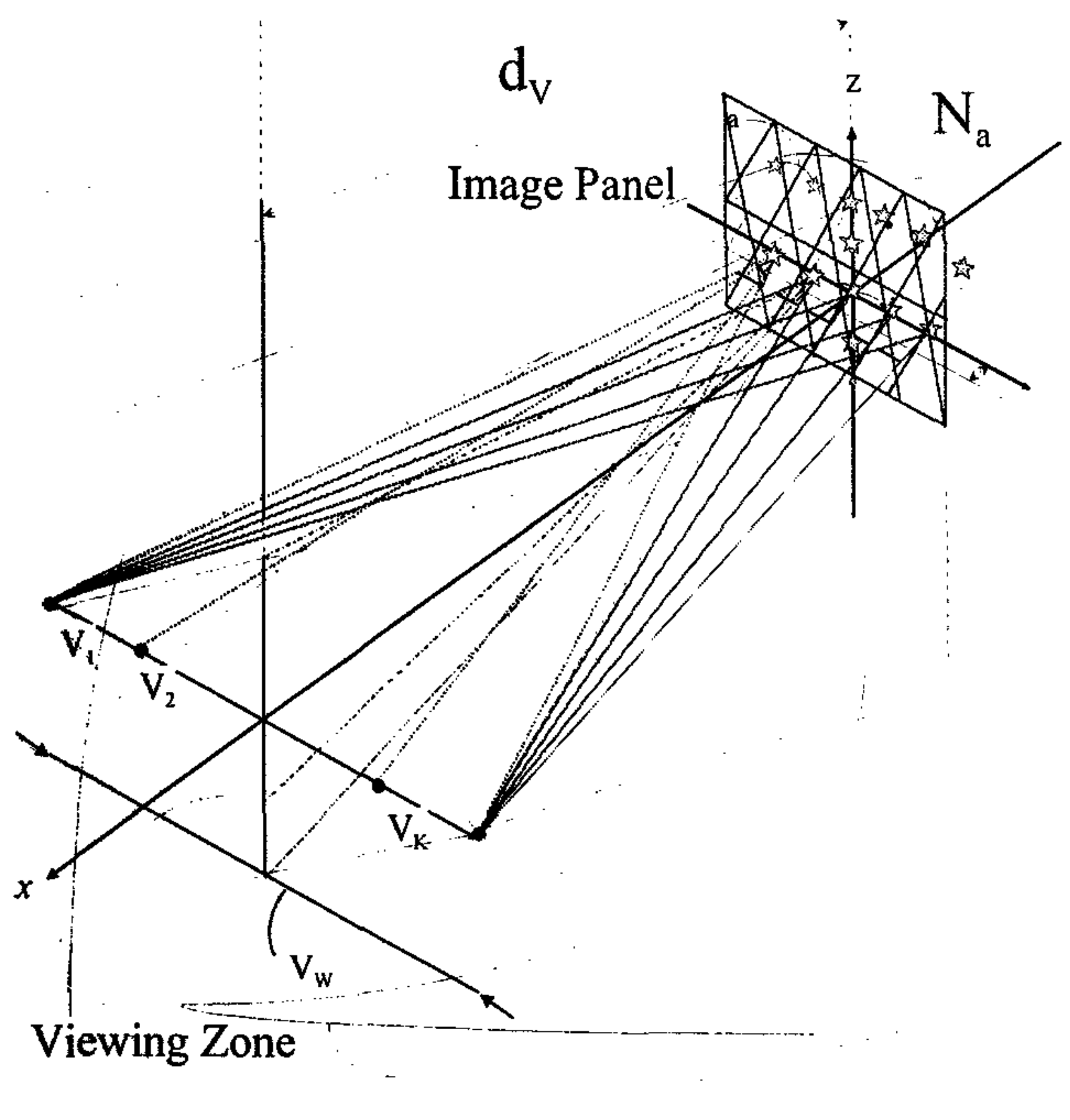

Fig. 3. Viewing Zone Cross-Section with a Diamond Shape

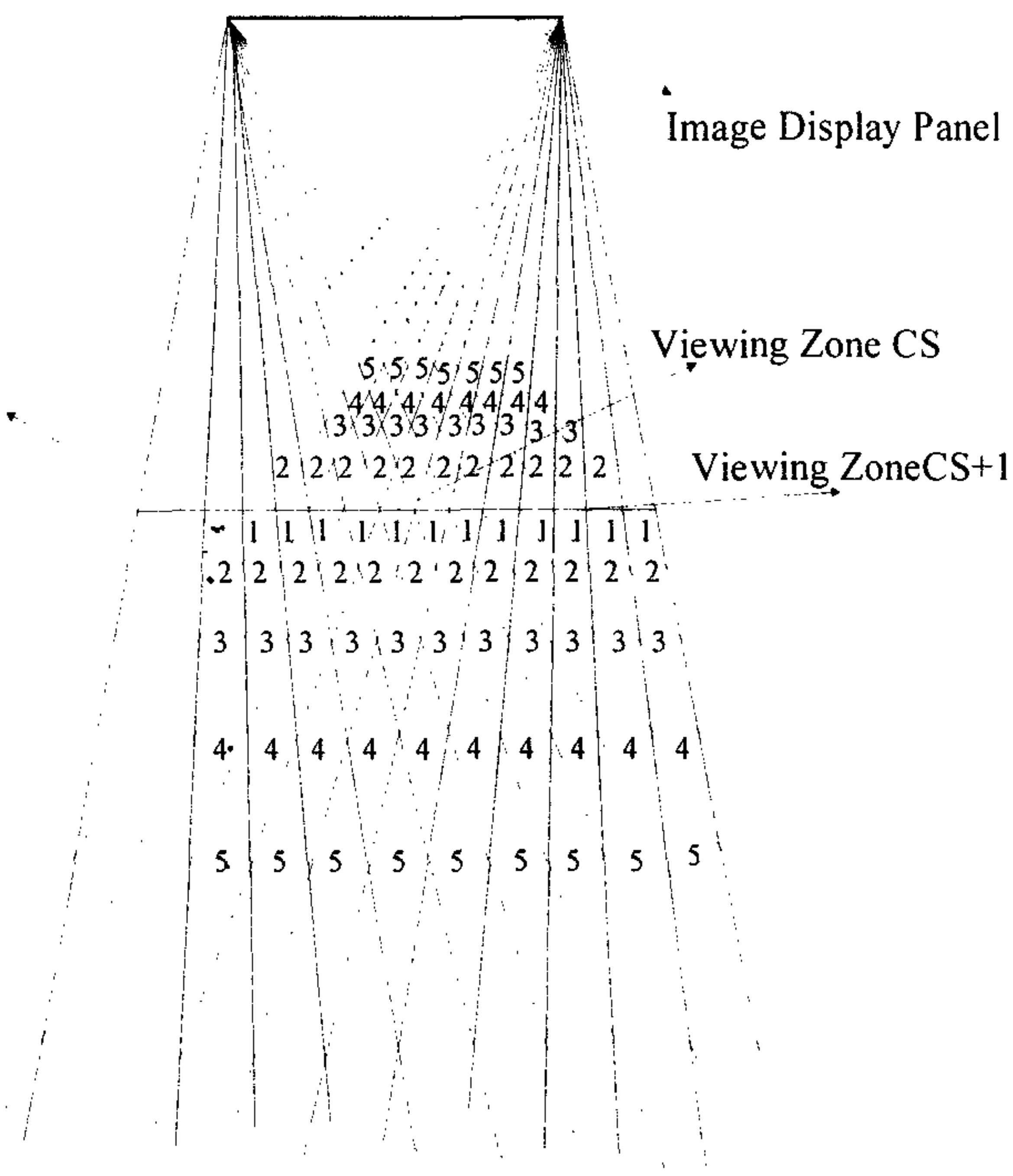

Fig.4. Viewing Zone Forming Geometry
(b) Panel Size > Viewing Zone Cross-Section

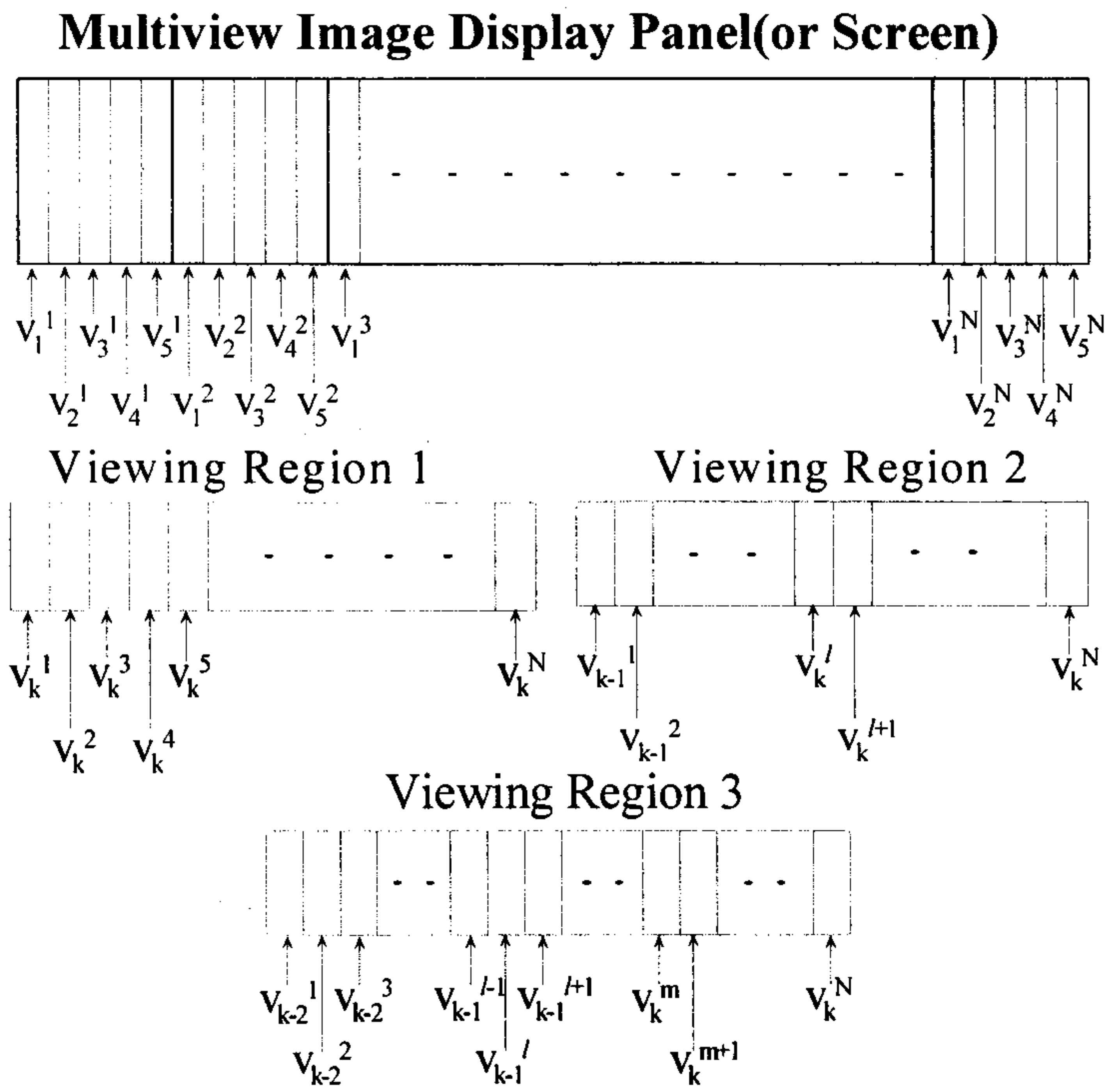

Fig. 5. An Example of Different View Image Patching.