A Stereoscopic System with Integration of Multiple Features

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1. Introduction

Recently, stereoscopic systems have been applied for robot vision systems, security systems, road traffic systems, etc. Stereoscopic systems detect three-dimensional (3-D) positions of target objects by observing them from different observing points and measuring image disparity from images at these points [1]. It is important for the systems to find correct corresponding points that are necessary for measurement of disparities. However, it is difficult to find correct corresponding points, because the number of candidates for corresponding points is n^2 for n object points. The conventional algorithms remove false corresponding points by using features or areas of images [2], [3]. However, these algorithms cannot enough remove false corresponding points. Because, these algorithms use only one out of features such as edges, colors, motions, etc. Therefore, we propose a stereoscopic system that can remove many false corresponding points with integration of features.

2. Proposed Stereoscopic Algorithm

We propose a stereoscopic algorithm utilizing multiple features such as edges and colors of target objects.

The edge feature is zero-cross point and zero-cross polarization. The algorithm extracts edge feature of objects from original images as shown in Fig. 1. Since original images generally have noise, the algorithm removes noise by using the Gaussian filter. The algorithm emphasizes edges of objects by the Laplacian filter. The zero-cross points are defined by the points where the image intensity extracted by Laplacian-of-Gaussian (LOG) filter crosses zero intensity. The zero-cross polarization is defined by the sign of a gradient of the image intensity extracted by LOG filter. If an input image is expressed by 8-bit, the color feature is extracted as dot patterns in 256^3 color planes as shown in Fig. 2.

The algorithm searches corresponding points of edge feature in N_P color planes. N_P is defined as $(256 - I_{E\text{-}C})^3$, where $I_{E\text{-}C}$ is the number of planes that are not used for the searching process. When N_P is one, the algorithm searches corresponding points in the only one color plane. When N_P is 256^3, the algorithm searches corresponding points in all color planes. By using the color feature, many edge features are divided into some groups that have few edge features by color planes, so candidates of corresponding points decrease. Therefore, the algorithm can easily find correct corresponding points.

The algorithm searches corresponding points as follow. First, on a condition where $I_{E\text{-}C}$ is 255, the algorithm searches corresponding points as shown in Fig. 3. The dark circles are zero-cross points in a color plane. The algorithm searches locations whose zero-cross point and polarization correspond between the left image and the right image. Disparities of locations where corresponding points are found are zero. Since the zero-cross points and polarization at the zero-disparity locations cause false corresponding points when the algorithm measures the other disparities, these zero-cross points and polarization are removed. After the algorithm searches locations whose disparities are zero, it searches locations whose disparities are +1 by shifting the right input image to right by one pixel. After this process, the algorithm searches location whose disparities are –1 by shifting the right input image to left by one pixel. If a search area of disparity is D, the algorithm continues these processes until it searches $\pm D$ disparities.

Second, the algorithm searches disparities from zero to $\pm D$ by the above processes on a condition where $I_{E\text{-}C}$ is 254. Thus, the algorithm gradually reduces $I_{E\text{-}C}$, and it finishes if new corresponding points are not found.

3. Simulation Results

Input images as shown in Fig. 4 are simple images whose two circles have the same disparity and different color. Simulation results express disparities with color. Positive disparities are expressed by red-tinged colors, and negative disparities are expressed by blue-tinged colors.

A simulation result utilizing only the edge feature is shown in Fig. 5(a). The search area D is 200. Disparities of two circles are different. These two circles have the same edge feature. Therefore, if the algorithm use only edge feature, the blue circle in the left image corresponds with the red circle in the right image.

In contrast, a simulation result utilizing the edge feature and the color feature is shown in Fig. 5(b). The search area D is 200. Disparities of two circles are same. If the algorithm uses the color feature, red circle does not correspond with blue circle. Therefore, false corresponding points that are caused by only one feature are removed. Thus, by using integration of multiple features, stereoscopic systems can remove false corresponding points.

Input images in real environment are shown in Fig. 6. A simulation result utilizing only the edge feature in the red rectangles of input images is shown in Fig. 7(a). The search area D is 24. Disparities of almost all objects are zero. Since this result represents that almost all objects are at the same depth, this is clearly false. In real environment, many objects have the same edge feature, so the algorithm finds false corresponding points in first process for searching zero-disparity locations.

A simulation result utilizing the edge feature and color feature is shown in Fig. 7(b). The edge feature does not correspond when the color feature is different. Therefore, disparities of almost all objects are different. Thus, the system utilizing multiple features can remove false corresponding points in real environment.

4. Conclusion

We proposed a stereoscopic algorithm that can remove false corresponding points with integration of multiple features in real environment. This algorithm can remove false corresponding points that are caused by one feature. As our future works, we are scheduled to develop a stereoscopic system that can correctly detect 3-D positions of objects by using more features and improving the algorithm of integration of multiple features.

References

[1] David Marr, "VISION A Computational Investigation into the HUMAN Reresentation and Processing of Visual Information," W. H. Freeman and Company, 1982.

[2] R. Mohan and R. Nevatia, "Using perceptual organization to extract 3-D structure," IEEE Trans. PAMI, Vol. 11, 1989.

[3] T. Kanade and M.Okutomi, "A stereo matching algorithm with an adaptive window: Theory and experiment," IEEE Trans. PAMI, Vol. 16, No.9, pp.920-932, 1994.

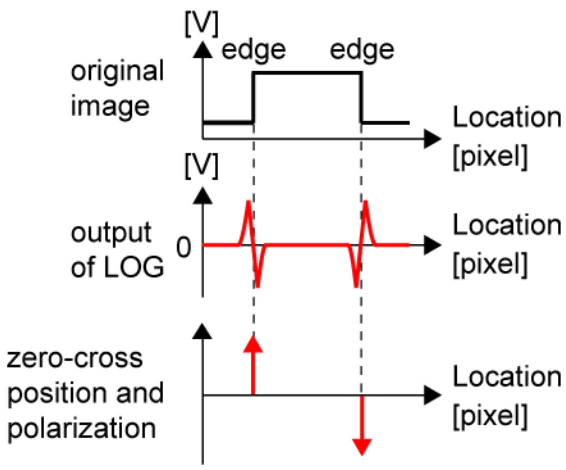

Fig. 1 Zero-cross points and polarization.

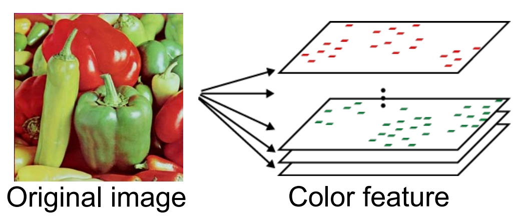

Fig. 2 Color feature extracted from an original image

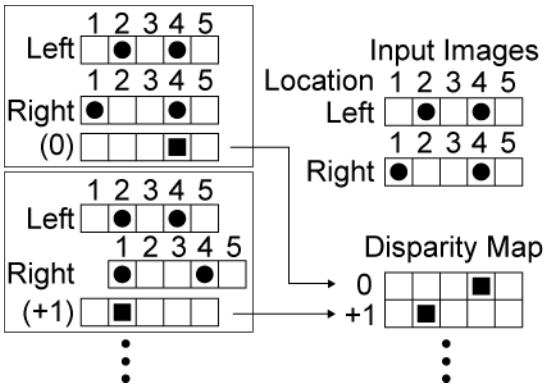

Fig. 3 Process to measure disparity by using zero-cross points and polarization in a color area.

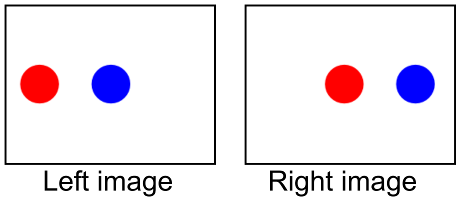

Fig. 4 Input images for our simulations.

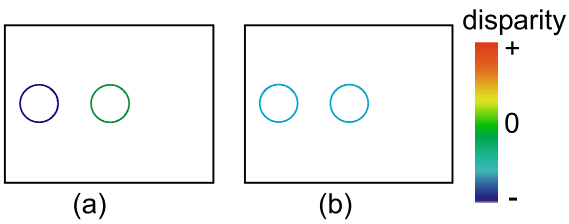

Fig. 5 Simulation results of a stereoscopic system (a) using only edge feature (b) using edge feature and color feature.

V

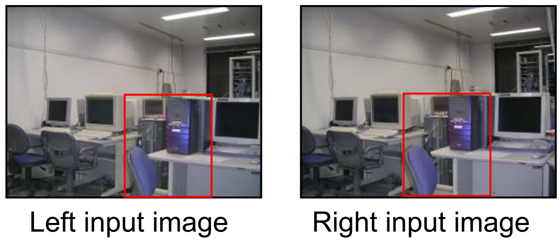

Fig. 6 Input image in real environment.

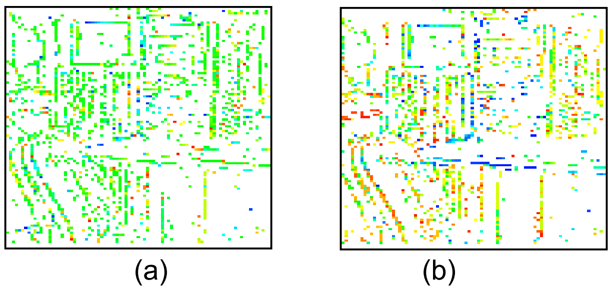

Fig. 7 Simulation result when input images are complex such as real environment (a) using only edge feature (b) using edge feature and color feature.

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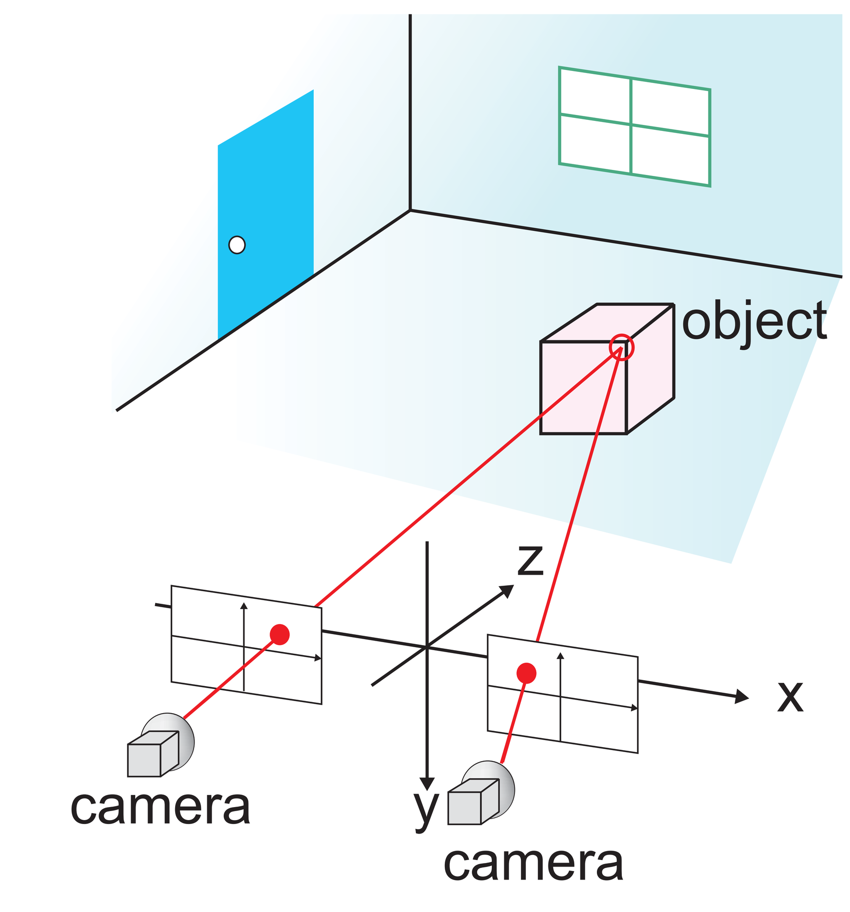
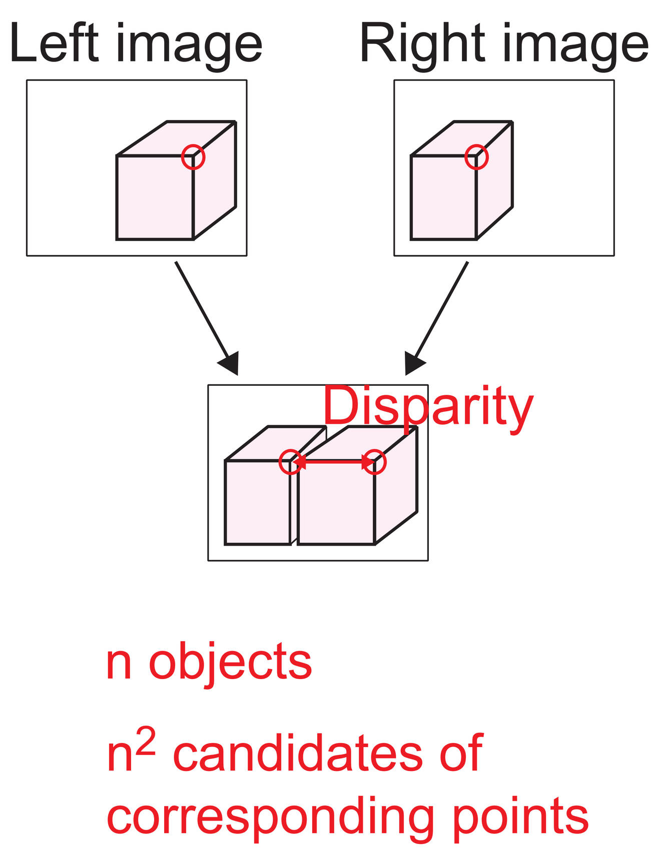
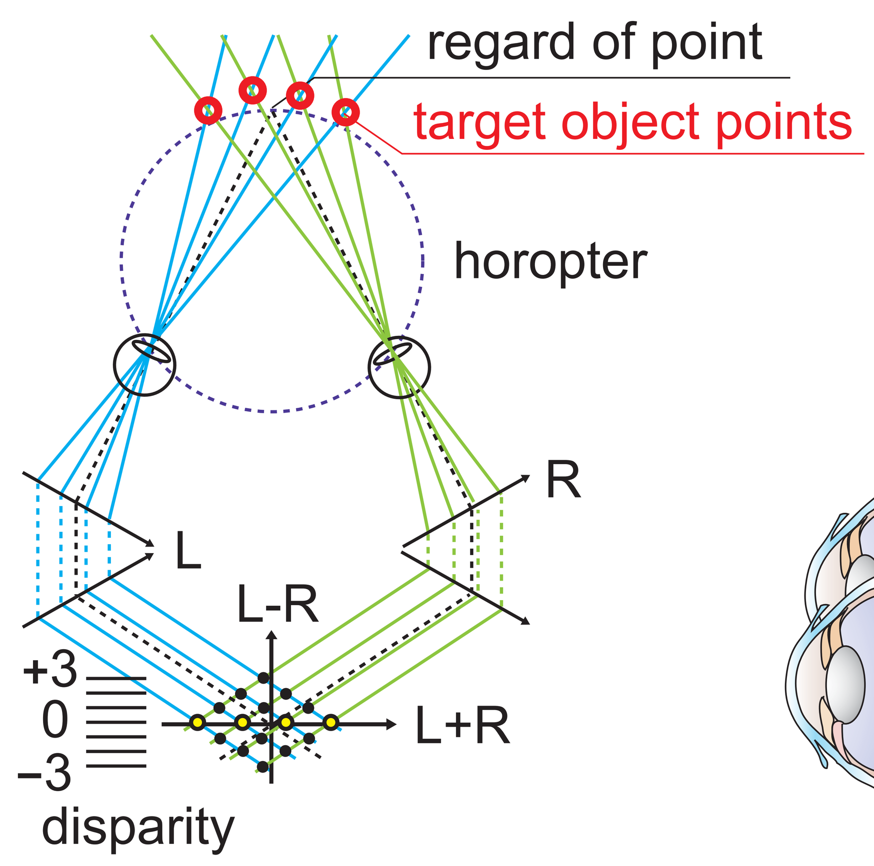
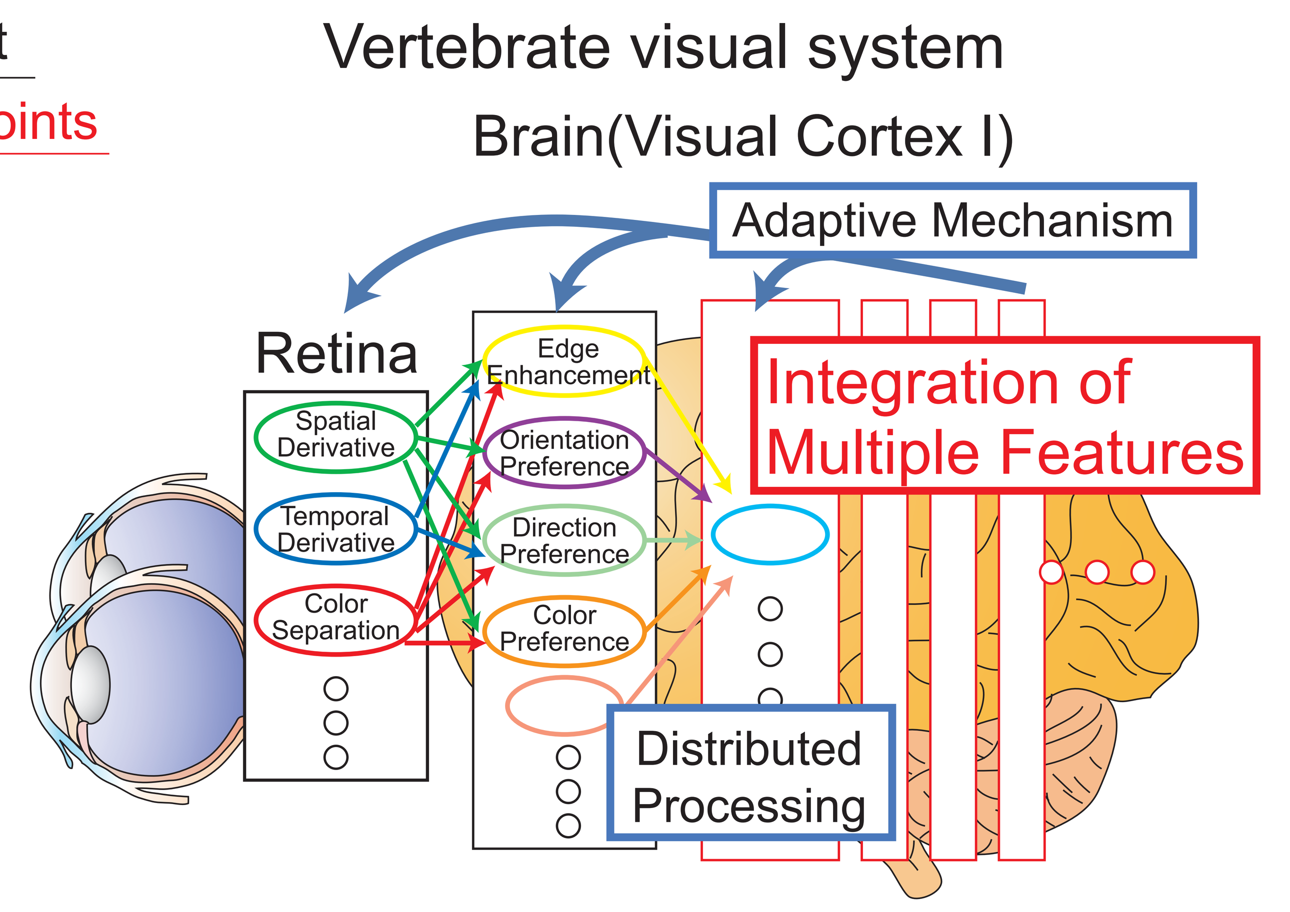
Introduction









Proposed Stereoscopic Algorithm

Input of original images

Extraction of multiple features of objects from original images

setting initial threshold ($I_{E\text{-}C}$ = 255)

Searching corresponding points and measurement their disparities

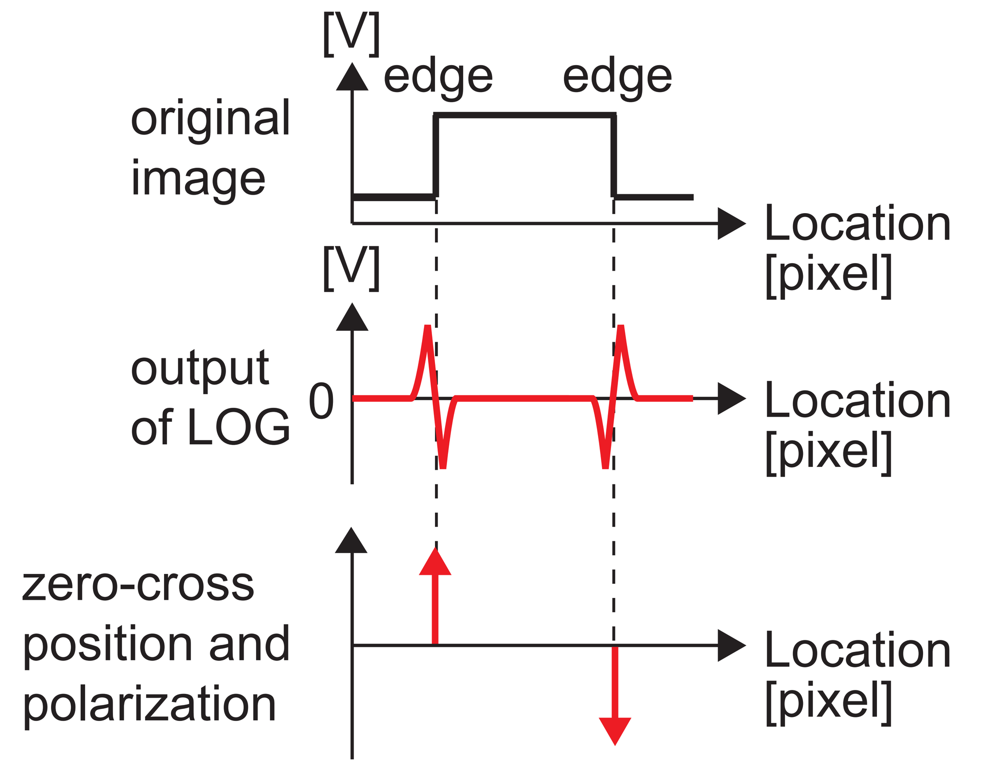
New corresponding points are found ?

YES → decreasing threshold

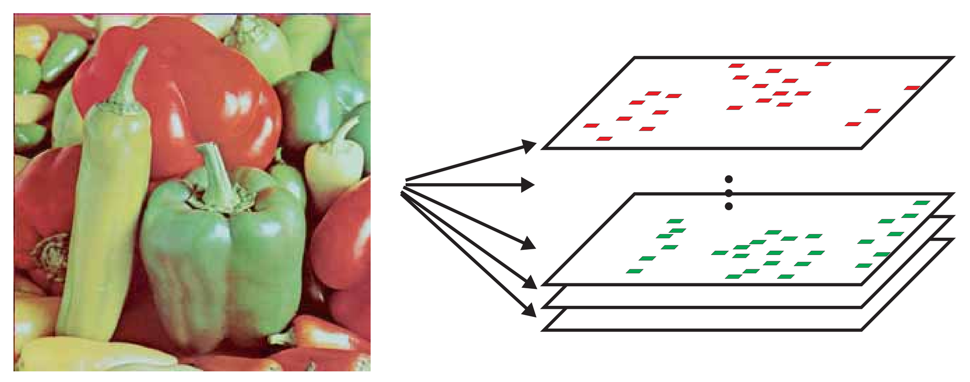
NO

Output of disparity map and finish

edge feature

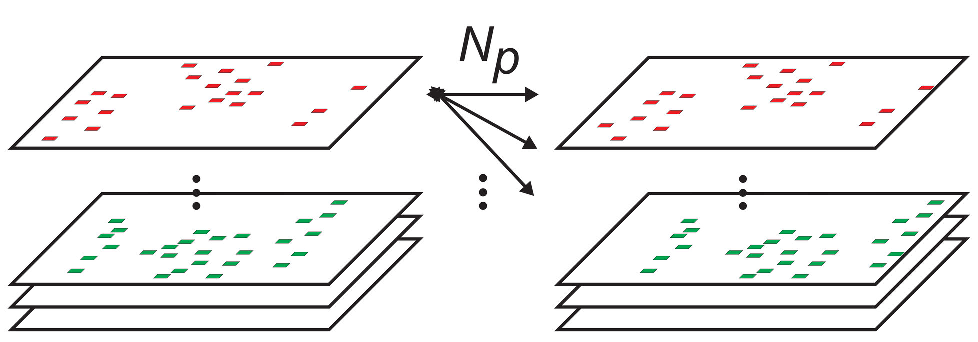


color feature



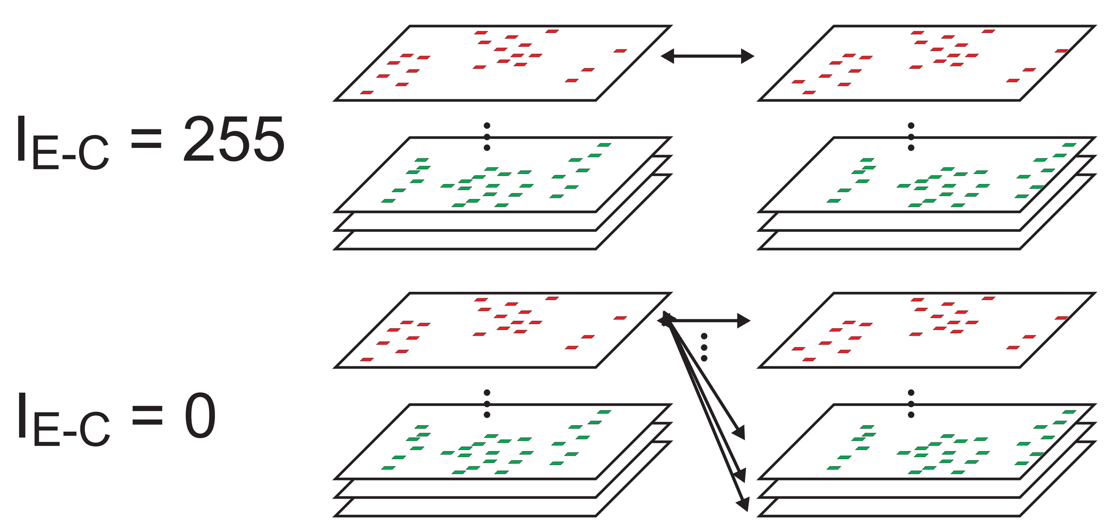
8-bit image 256^3 color planes

Searching corresponding points of edge feature in N_p right color planes for each of left color planes

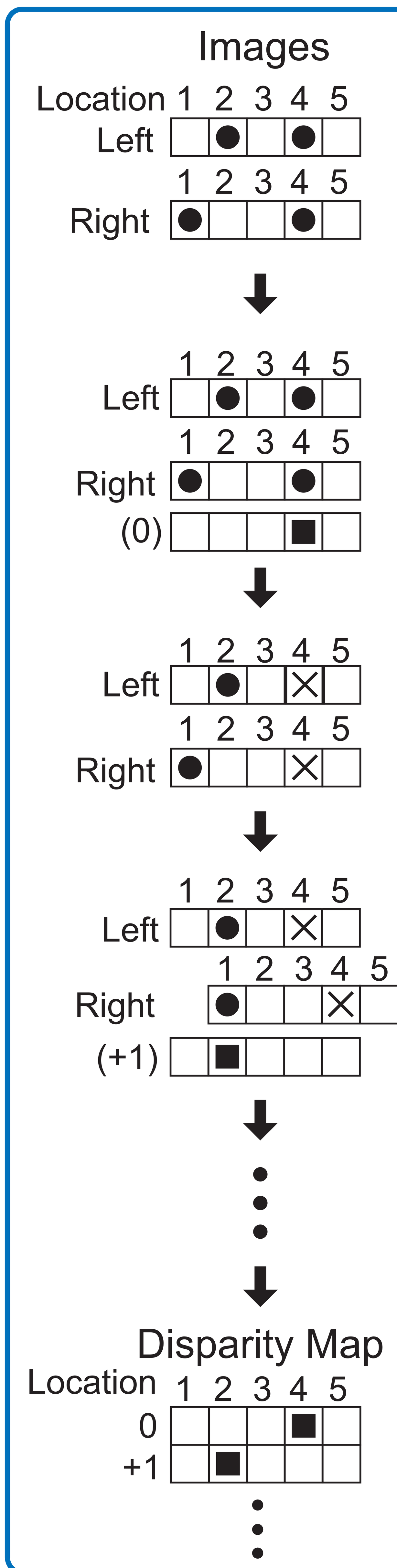


$$N_p = (256 - I_{E\text{-}C})^3$$

$I_{E\text{-}C}$ is the number of color planes that are not used for the searching process.



By using color feature, many edge features are divided into some groups that have few edge features, so candidates of corresponding points decrease.



Input of images

Searching corresponding points at zero-disparity by using edge features in N_p right color planes for each of left color planes

Removing edge features at zero-disparity locations

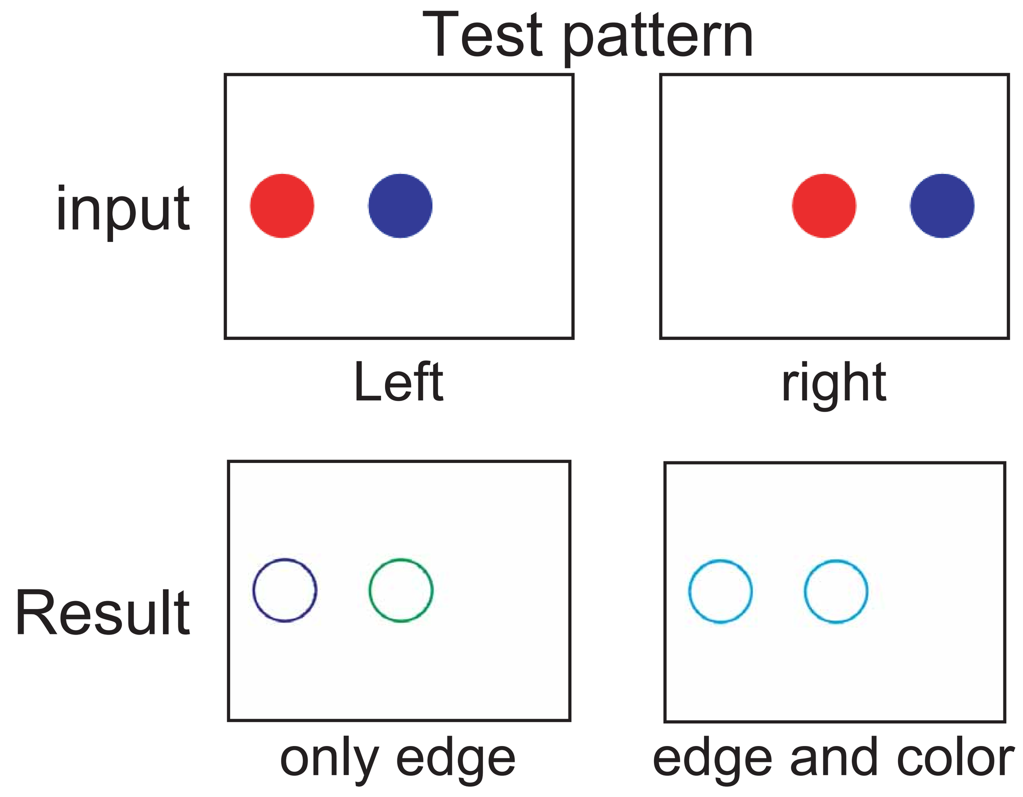
Searching corresponding points at +1 disparity by shifting the right image to right by one pixel

Continuing above processes until the algorithm searches ±D disparities

Creating disparity map

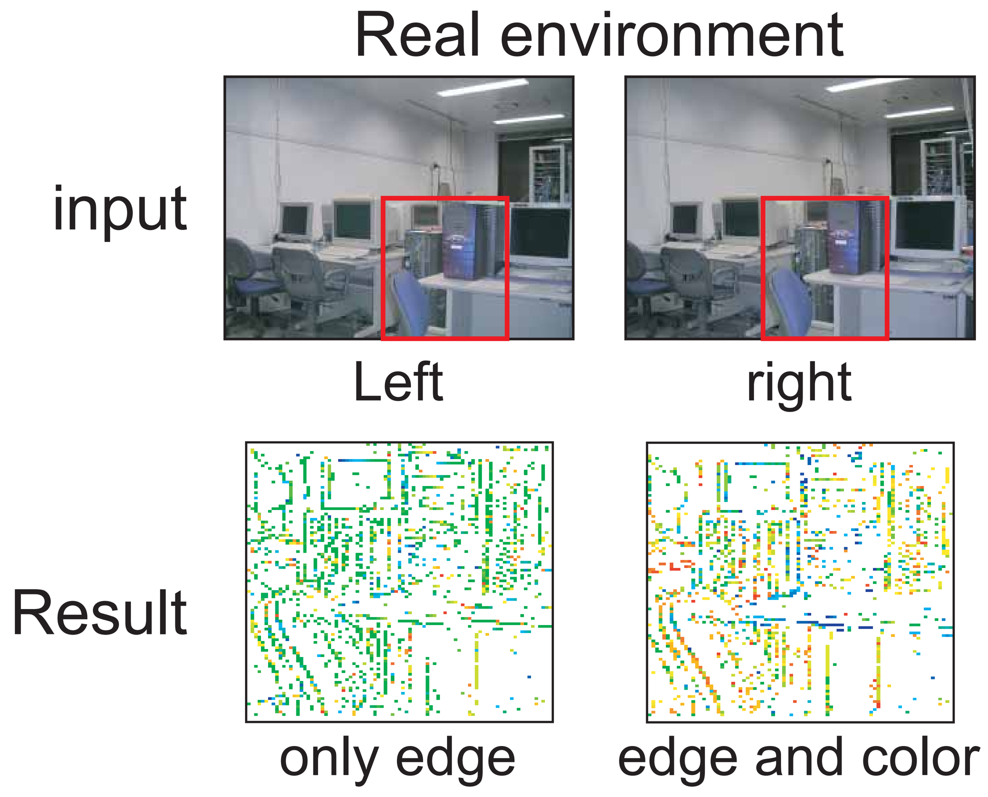
Simulation Results

Test pattern



By using only edge feature, blue circle in left image correspond red circle in right image. By using edge and color feature, this error does not occur.

Real environment



By using only edge feature, almost all objects are at the same depth. By using edge and color feature, each of objects is at different depth.

Conclusions

We proposed a stereoscopic algorithm that can remove false corresponding points with integration of multiple features in real environment.

Edge feature is used for the algorithm to each corresponding points.

Color feature is used for the algorithm to decrease candidates of corresponding points of edge feature.