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Detection and Extraction of Camouflaged Segments using Distance Matching Function

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Abstract: Camouflage is an art of hiding an object by making it appear similar to the background in such a way that human vision system fails to detect or locate the hidden object. When the size of camouflaged segments present in a texture becomes smaller and smaller and when the texture of the camouflaged segments is similar to that of the background, it becomes difficult for the human vision system to discriminate between the original background and the camouflaged segments. In the present paper, we have designed and proposed a new algorithm for the detection and extraction of such camouflaged segments in synthetic textures using one-dimensional distance matching function, which is considered to be one of the derivatives of co-occurrence matrix. The proposed algorithm doesn't need the knowledge about the background and it can extract the camouflaged segments and highlight even pixel-wise change in gray level intensity within the camouflaged segments with reference to the background texture.

Keywords: Distance matching function, Periodicity, Texel, Camouflage

1. Introduction

Camouflage is an outward semblance that misrepresents the true nature of something. Camouflage is abundantly found in nature. Camouflaging is sometimes purposely created by soldiers during war. When the texture of the foreground becomes similar to that of the background, it becomes difficult for human visual system to discriminate between the foreground and the background. In such cases, even the statistical properties of the hidden object and the background may not vary much. Camouflage related work can be basically divided into two areas, namely, Camouflage assessment and design and Camouflage breaking. Camouflage breaking is very important in areas like military tactics and is also useful in background subtraction. It also helps in understanding of extraction of non-camouflaged objects and in developing algorithm to locate object in the foreground. Literature survey reveals that there are very limited researches done in the area of identifying camouflaged segments in an image.

One of such methods is Convexity-based camouflage breaking method by Ariel Tankus and Yehezkel Yeshurun in 1998 [1]. This method can highlight the places of high convexity. This method is effective in locating objects with convex surfaces like vases or jars in a background of a plain texture. This algorithm involves calculation of derivative of argument of intensity gradients and sum of the derivatives at various orientations. This leads to creation of an output image that highlights the convex areas of the original image. This method is more robust, but it is capable of highlighting only the convex portion of the foreground object in the texture against the background. Nagabhushan and Nagappa developed the co-occurrence and Canny method and published their finding in 2004 [4]. This work on detection of camouflaged segment involves determination of properties of co-occurrence matrices and repeated application of Canny edge detector. This method consists of two phases. The first part is to determine if there is a camouflaged object in the image by creating gray level co-occurrence probability matrix, which is based on second order probability distribution and assessing the co-occurrence matrix's texture parameters like energy, entropy, maximum probability, contrast, inverse difference moment and correlation, and comparing them with those of the background. Once it is known that there is a camouflage object within the image, the second part of the process starts. The second part is to achieve effective visualization of camouflage objects by repeatedly applying Canny edge detector. But in this method, knowledge about the background texture is a must. Nagabhushan, Lalitha and Nagappa proposed another method to locate the camouflaged target, wherein detection of camouflaged segment was aimed at using local texture analysis in smaller windows [5]. This algorithm also consists of two phases. The first one is the learning and locating phase where a window is placed in the first block of the image assuming that the camouflaged portion is present in the interior of the image and thus the first block represents the intrinsic background texture. The second phase is the recognition phase where the first and second moments were analyzed to identify the presence of camouflaged segments. This method also calls for the information about the background texture. In the present method, the distance matching function has been thought of as the base tool for the detection of camouflaged object without the need of knowledge about background texture. As many textures can be thought of combination of periodic repetition of basic elements or building blocks called texels or texture elements [2], in this work, we have devised a new method for detection of camouflaged segments from a synthetic textural image and extraction of the camouflaged segments with the help of texel extracted using distance matching function. Basically the idea is to extract the periodic texel from the image and to identify or locate the camouflaged segments. As far as analysis on texture is concerned, there are several methods like Statistical method, Structural method and

Hybrid method. Texels can be analyzed with the help of methods like Fourier analysis, co-occurrence matrices, auto-correlation and Runey's generalized entropies [3]. However, Fourier transform and autocorrelation methods are not suitable for analyzing periodic textures of finite size, and Runey's generalized entropies can be used to identify square-shaped texel in regular textures, but co-occurrence matrix is very effective method for extraction of useful measures form a texture for finding its periodicity [7]. Distance matching function which is considered to be one of the derivatives of cooccurance matrix gives a powerful measure of periodicity [6]. Distance matching function is more advantageous than other methods because of the following facts [7]:

- Not so sensitive to noise or dispersions
- Suitable for textures with limited size
- Faster calculation speed
- Suitable for identification of any kind of periodicity in textures

The one-dimensional distance matching function, d(x), of a row or column vector, f, of size N pixels can be defined as [6],

$$d(x) = \sum_{i=0}^{N-x-1}[f(i) - f(x+i)]^2$$

where, x refers to the number of pixels in the row or column direction. In order to obtain the periodicity in a row or column direction, d(x) can be calculated for different values of x, which can be, at the maximum, the image size. The lowest value of x that makes the distance matching function zero is a direct measure of periodicity. For example, let us consider the following row vector 'f' of size m=20:

f = [1 2 3 1 1 2 3 1 1 2 3 1 1 2 3 1 1 2 3 1]

The distance matching function for the function 'f' can be calculated as below:

$d(x=0)=(1-1)^2+(2-2)^2+(3-3)^2+(1-1)^2+\ldots+(1-1)^2 = 0$
$d(x=1)=(1-2)^2+(2-3)^2+(3-1)^2+(1-1)^2+\ldots+(3-1)^2 = 30$
$d(x=2)=(1-3)^2+(2-1)^2+(3-1)^2+(1-1)^2+\ldots+(2-1)^2 = 45$
$d(x=3)=(1-1)^2+(2-1)^2+(3-2)^2+(1-3)^2+\ldots+(1-1)^2 = 24$
$d(x=4)=(1-1)^2+(2-2)^2+(3-3)^2+(1-1)^2+\ldots+(1-1)^2 = 0$
… … …

Thus the distance matching function for the entire row shows periodic pattern as shown in the plot below:

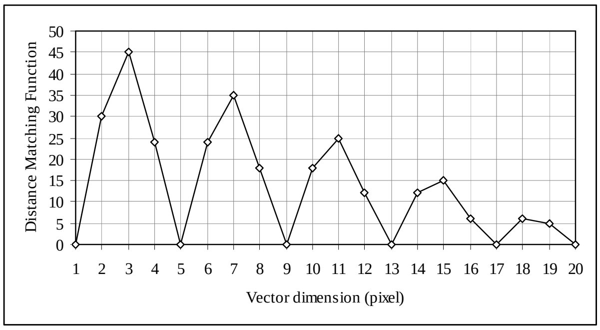

Figure 2.1: Distance matching function for the function 'f'

From the above plot of distance matching function for the function 'f', it can be concluded that the periodicity is 4 pixels.

Let us consider another function 'g' which is formed using the function 'f', which is periodic, and a patch of camouflaged points shown in bold letters as below:

g = [1 2 3 1 1 2 3 1 1 2 3 1 1 2 3 1 1 2 **6 7**]

The distance matching function for this function 'g' can be calculated in the similar manner and shown as below:

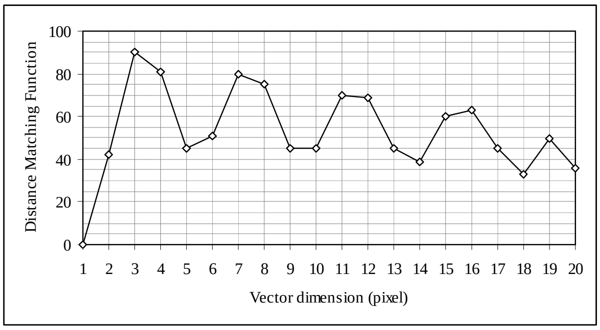

Figure 2.2: Distance matching function for the function 'g'

From figure.2, it is clear that the distance matching function doesn't reproduce zeros for the function 'g' because of the presence of the 19th and 20th camouflaged pixels and this could be taken as a measure to identify whether a row or column is camouflaged and this fact is utilized in the present work.

2. Proposed Algorithm

The change in distance matching function for a row or column of an image due to the presence of camouflaged segments has been taken as the base tool for the present work and a new algorithm has been proposed based on following assumptions:

- All the rows or columns are not affected by camouflaged objects
- The camouflaged objects may be present anywhere in the image either in isolated or cluttered form.

The algorithm includes the following steps:

(i) Compute the one-dimensional distance matching function for all the rows and get the row-periodicities (P_R)
(ii) Compute the one-dimensional distance matching functions for all the columns and get the column-periodicities (P_C)
(iii) Divide the image to get image blocks of size determined from row and column periodicities
(iv) Construct the texel of size 'column periodicity' x 'row periodicity' using gray values obtained from rows or columns having periodicities
(v) Perform Logical XOR operation between the texel and each image block without overlapping the other blocks
(vi) Get the location of '1' from the XOR operation and highlight them in the image as camouflaged segment
(vii) Replace all the camouflaged objects by the texel elements so as to get decamouflaged texture

3. Illustration of the proposed algorithm

Let us consider an image of size 9 x 9 with gray values as given below:

Table 4.1: Matrix showing gray values of image of size 9 x 9

1	2	3	1	2	3	1	2	3
2	**8**	6	2	4	6	2	4	6
3	6	8	3	6	8	3	6	8
1	2	3	1	2	3	1	2	3
2	4	6	2	4	6	2	4	6
3	6	8	3	6	8	**2**	**4**	8
1	2	3	1	2	3	1	2	3
2	4	6	2	4	6	2	4	6
3	6	8	3	6	8	3	6	8

Based on distance matching function for all rows and columns, the periodicities can be found out as explained in our earlier discussion and can be given as below:

Table 4.2: Matrix showing gray values with row and column periodicities

		Column number									P_R
		1	2	3	4	5	6	7	8	9	
Row number	1	1	2	3	1	2	3	1	2	3	**3**
	2	2	**8**	6	2	4	6	2	4	6	--
	3	3	6	8	3	6	8	3	6	8	**3**
	4	1	2	3	1	2	3	1	2	3	**3**
	5	2	4	6	2	4	6	2	4	6	**3**
	6	3	6	8	3	6	8	**2**	**4**	8	--
	7	1	2	3	1	2	3	1	2	3	**3**
	8	2	4	6	2	4	6	2	4	6	**3**
	9	3	6	8	3	6	8	3	6	8	**3**
P_C		**3**	--	**3**	**3**	**3**	**3**	--	--	**3**	

Based on the row and column periodicities of the image, size of the texel can be found as 3 x 3 and the input image can be divided into blocks of size same as that of texel as given below:

Table 4.3: Matrix showing input image as image blocks

1	2	3	1	2	3	1	2	3
2	**8**	6	2	4	6	2	4	6
3	6	8	3	6	8	3	6	8
1	2	3	1	2	3	1	2	3
2	4	6	2	4	6	2	4	6
3	6	8	3	6	8	**2**	**4**	8
1	2	3	1	2	3	1	2	3
2	4	6	2	4	6	2	4	6
3	6	8	3	6	8	3	6	8

Based on distance matching function, rows which have periodicities can be extracted from the image and given as below:

Table 4.4: Matrix showing the gray values of rows which have periodicities

Row-1 or 4 or 7	1	2	3	1	2	3	1	2	3
Row-5 or 8	2	4	6	2	4	6	2	4	6
Row-3 or 9	3	6	8	3	6	8	3	6	8

The texel can be obtained from the above matrix based on row and column periodicities i.e., size of the texel, and thus the texel for the image can be given as below:

Table 4.5: Matrix showing gray values of texel

1	2	3
2	4	6
3	6	8

When logical XOR operation is performed between the texel and each image block, the output will be either '1' if there is camouflage or zero if there is no camouflage. Thus for the image blocks the result of XOR is as below:

Table 4.6: Matrix showing the result of XOR operation between image blocks and texel

1	0	0
0	0	1
0	0	0

As the result '1' indicates the presence of camouflage in the image, the boundary of the image block containing camouflaged objects can be highlighted and also the camouflaged objects can be replaced with texel elements to get the decamouflaged image as given below:

Table 4.7: Matrix showing gray values of image after correction

1	2	3	1	2	3	1	2	3
2	4	6	2	4	6	2	4	6
3	6	8	3	6	8	3	6	8
1	2	3	1	2	3	1	2	3
2	4	6	2	4	6	2	4	6
3	6	8	3	6	8	3	6	8
1	2	3	1	2	3	1	2	3
2	4	6	2	4	6	2	4	6
3	6	8	3	6	8	3	6	8

4. Experiments and Results

Several images with isolated and cluttered camouflaged objects were tested and the following output images were obtained:

- Texel of the image
- Image showing boundaries of camouflaged objects
- Image in which pixel locations where additional gray values are present in the image blocks with reference to

those of texel and pixel locations where additional gray values which are supposed to be present in the image blocks are missing with reference to those of texel shown highlighted in color

- Corrected image after decamouflaging

The images tested and the results are as follows:

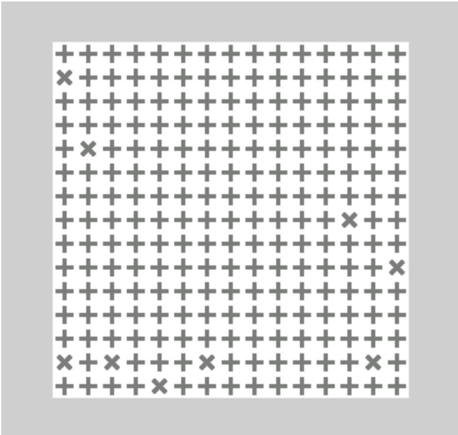

Figure 5.1: Test image-1 consisting of isolated ‘x’ camouflaged in ‘+’ background

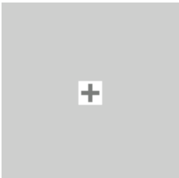

Figure 5.2: Texel of test image-1

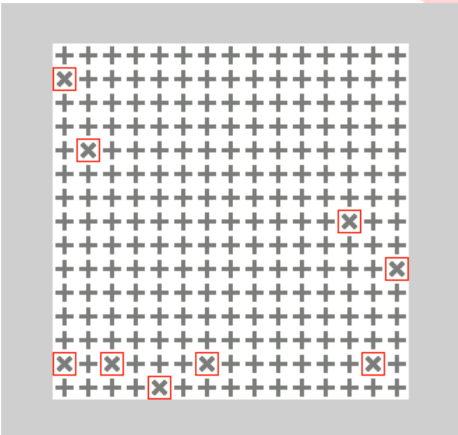

Figure 5.3: Image with boundaries of camouflaged objects highlighted

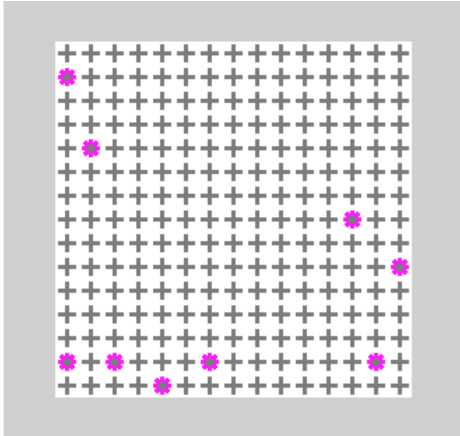

Figure 5.4: Image showing camouflaged pixels in color

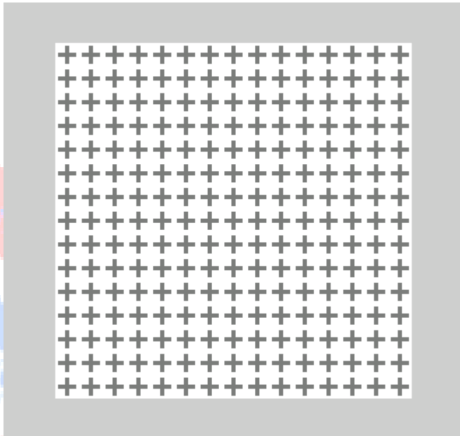

Figure 5.5: Image after decamouflaging of test image-1

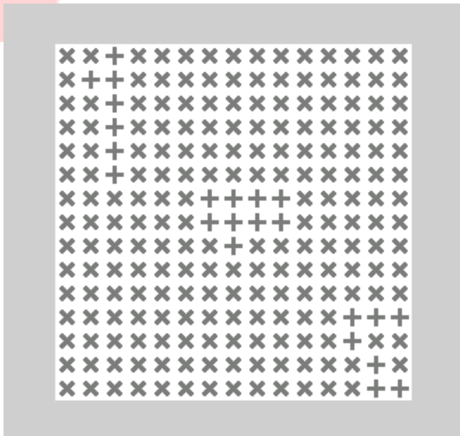

Figure 5.6: Test image-2 consisting of cluttered ‘+’ camouflaged in ‘x’ background

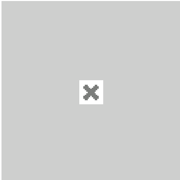

Figure 5.7: Texel of test image-2

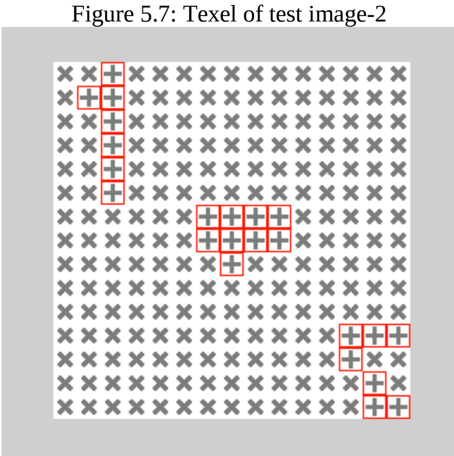

Figure 5.8: Image with boundaries of camouflaged objects highlighted

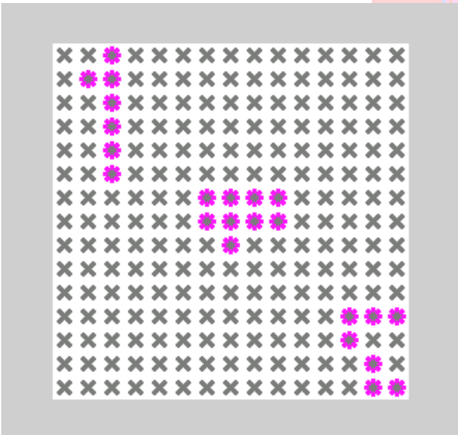

Figure 5.9: Image showing camouflaged pixels in color

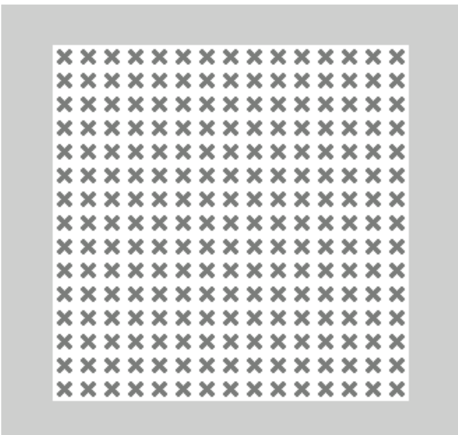

Figure 5.10: Image after decamouflaging of test image-2

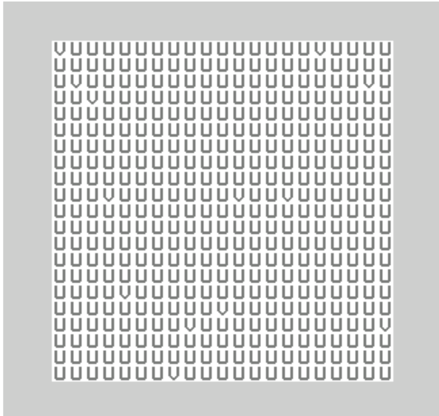

Figure 5.11: Test image-3 consisting of isolated 'V' camouflaged in 'U' background

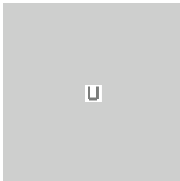

Figure 5.12: Texel of test image-3

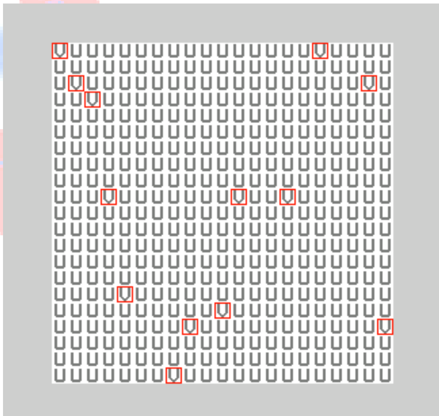

Figure 5.13: Image with boundaries of camouflaged objects highlighted

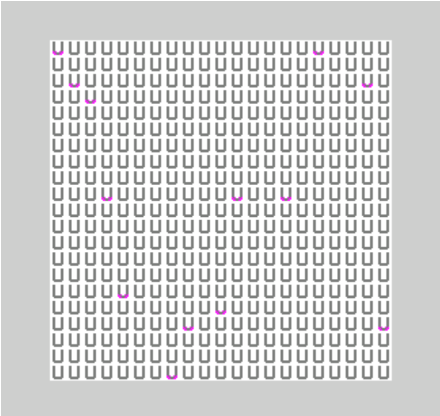

Figure 5.14: Image showing camouflaged pixels in color

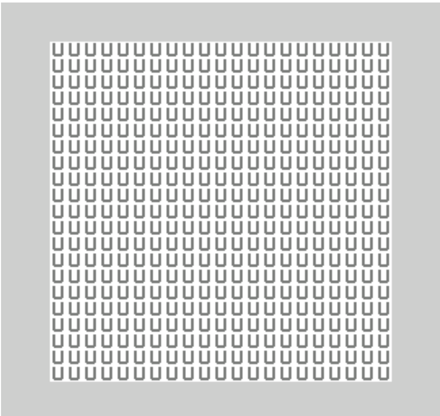

Figure 5.15: Image after decamouflaging of test image-3

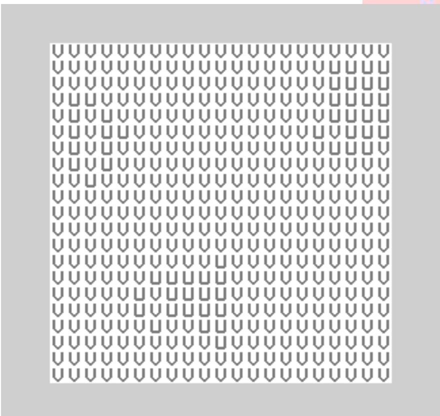

Figure 5.16: Test image-4 consisting of cluttered ‘U’ camouflaged in ‘V’ background

Figure 5.17: Texel of test image-4

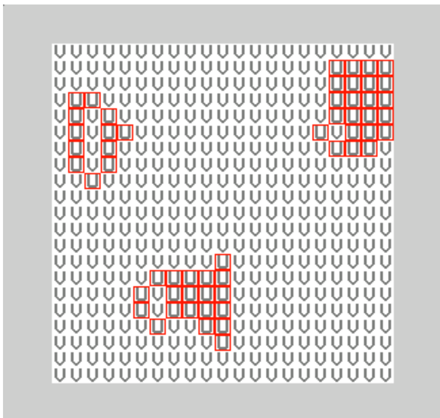

Figure 5.18: Image with boundaries of camouflaged objects highlighted

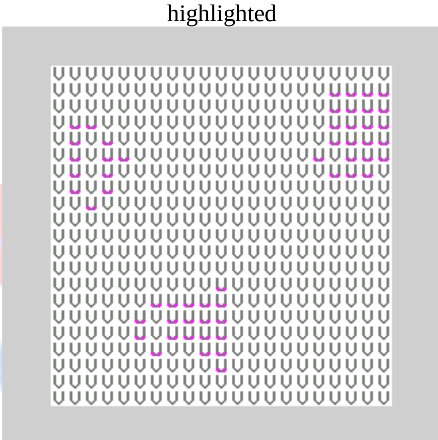

Figure 5.19: Image showing camouflaged pixels in color

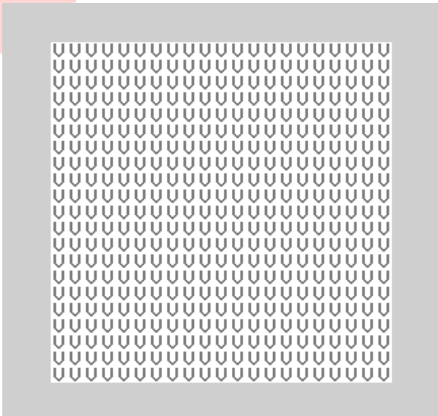

Figure 5.20: Image after decamouflaging of test image-4

The results of the experiments show that this method is very effective for synthetic images with camouflaged objects either in isolated or cluttered form and this method can highlight the boundary of camouflaged objects and also the locations where additional gray values are present with reference to those of background texel and the locations where gray values are to be present are missing with reference to those of background texel. However, the algorithm has been tested only for synthetic images and application of distance matching function for natural textures is an open area for research.

5. Conclusions

In the present research work, the concept of distance matching function, which was originally utilized for determination of textural periodicities, has been employed and a new algorithm has been developed for detection of camouflaged segments in synthetic textures. The algorithm developed is simple and is found to be very efficient for detection of both isolated and cluttered camouflaged segments in synthetic textures and also in decamouflaging. The present algorithm doesn't need the knowledge about the background texture, which is a must in other statistical methods found in literature.

6. References

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