Applications of Electromagnetic Phenomena in Electrical and Mechanical Systems
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Dynamic image cognition along with eigen patterns

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ABSTRACT: Principal purpose of this paper is to realize the function of human eyes on the computers by extracting the essential characteristics of target object. We firstly consider a way of characteristic extraction to the target digital image. Hence, we propose the eigen pattern representing characteristics of target digital image. The key idea of the eigen pattern is to extract unique information which is independent of resolution and spatial position of the target digital image on the screen. Furthermore, this eigen pattern methodology is generalized to the dynamic digital image.

1 INTRODUCTION

Many technologies employing digital computers are developed to emulate the human brain functions, e.g. artificial intelligent (AI) and artificial neural network (ANN). Even if we limit ourselves to only the function of human eyes, no computer image processing technique could realize that function exactly. This is because the human brain is informed by seeing, hearing, etc, which makes it possible to cognize a target object. Furthermore, the human brain extracts the essential characteristics of the target object by seeing and hearing. The extraction of such essential characteristics from the target object is of paramount importance in computer science, but this has not been accomplished yet.

In this paper, target objects of the image cognition are defined as cognizable information by the human eye, and they are called "visualized information". The picture or image obtained by a camera is considered as visualized information. Infrared and electron microscope are also capable of visualizing something that is directly invisible for human eyes. Even if the information is invisible, the signals obtained make it possible for the human eye to cognize the information by specific ways.

In the case of the human brain, the information is recognized by seeing, hearing and so on. Information by seeing and hearing is classified into two kinds of audiovisual information. One is encoded audiovisual information such as an encoded character and a language by a specific rule. The other is non-encoded audiovisual information. The visualized information such as a visualized image is one of the non-encoded audiovisual information. Human being senses some characteristics from the visualized information, however, it is important for computer sciences to extract the essential characteristics from the visualized information in order to mimic the human brain.

A digital image on two-dimensional plane is composed of a set of the pixels, and is represented by a geometrical arrangement of the pixels. In the case of a color image, the pixels relate to the red, green and blue color information. In the case of a monochromatic image, the pixels relate to the light and shade. Thereby, the digital images depend on their resolution and spatial position on the screen. The key idea of characteristic extraction is to introduce the eigen pattern, that represents the essential characteristics of digital images independent of their resolution and spatial position on the screen [1]. As a result, our approaches have succeeded in cognizing images beyond the human eyes.

2 EIGEN PATTERN OF DIGITAL IMAGES

2.1 Eigen pattern elements

The eigen pattern of a color image is composed of eigen vectors of three components; intensity, tone, and color component. The elements of intensity eigen vector are given by the sum of red, green, and blue components of each pixel. The tone of the eigen pattern consists of two eigen vectors. Since the tone is a ratio of color pixel, the tone eigen vectors can be given by two components of an image. The color component of the eigen pattern is represented by three eigen vectors; red, green and blue eigen vectors. The elements of color component eigen vectors are given by the value of red, green and blue components of each pixel, respectively. The eigen pattern of a monochromatic image is composed of the value of light and shade of each pixel.

2.2 Intensity eigen vector

At first, when we denote $I_{\text{int},i}$ as an intensity value of i-th pixel, the intensity value is given by a simple sum or a root mean square of red, green, and blue components,

$$I_{\text{int},i} = R_i + G_i + B_i$$
$$I_{\text{int},i} = \sqrt{R_i^2 + G_i^2 + B_i^2}, \tag{1}$$

where R_i, G_i and B_i represent the value of red, green and blue components of a pixel, respectively. The intensity distribution is represented by I_{int}`

$$I_{\text{int}} \in I_{\text{int},i}, \quad i = 1,2,3,\cdots,p, \tag{2}$$

where p is the number of pixels. Second, I_{int} is normalized with the dynamic range D. The normalized intensity distribution I_{int}^D is given by

$$I_{\text{int}}^D \in \text{Round}\left[D \times \frac{I_{\text{int},i}}{\text{Max}[I_{\text{int}}]}\right], \quad i = 1,2,3,\cdots,p, \tag{3}$$

where the functions Round and Max work as rounding up to integer number and extracting the maximum value, respectively. Third, the number of pixels having each intensity value from 1 to D is counted. Thereby, the normalized intensity distribution I_{int}^D is transformed into a histogram of the intensity distribution. Finally, the intensity eigen vector $\mathbf{E}_{\text{int}}$ is obtained as a normalized histogram of intensity value.

2.3 Tone eigen vector

The tone is a ratio of red, green and blue components of each pixel. Let us consider the red component of tone distribution. At first, let $I_{\text{tone},R}$ be the red component of tone distribution. Then, the tone distribution is given by

$$I_{\text{tone},R} \in \frac{R_i}{I_{\text{int},i}}, \quad i = 1,2,3,\cdots,p. \tag{4}$$

Second, $I_{\text{tone},R}$ is normalized with the dynamic range D.

$$I_{\text{tone},R}^D \in \text{Round}\left[D \times \frac{I_{\text{tone},R,i}}{\text{Max}[I_{\text{tone},R}]}\right], \quad i = 1,2,3,\cdots,p. \tag{5}$$

Third, the number of pixels having each tone value from 1 to D is counted. Finally, the normalized histogram of each tone value is transformed into the tone eigen vector of red component $\mathbf{E}_{\text{tone},R}$. The other eigen vectors of green $\mathbf{E}_{\text{tone},G}$ and blue $\mathbf{E}_{\text{tone},B}$ are given in much the same way as $\mathbf{E}_{\text{tone},R}$.

2.4 Color component eigen vector

The color component eigen vector is given in terms of the value of red, green and blue components of an image. Let us consider the red component distribution. At first, let $I_{\text{comp},R}$ be the red component distribution. Then, the red component distribution is given by

$$I_{\text{comp},R} \in R_i\,,\quad i = 1,2,3,\cdots,p\,. \tag{6}$$

Second, $I_{\text{comp},R}$ is normalized with the dynamic range D.

$$I_{\text{comp},R}{}^{D} \in \text{Round}\left[D \times \frac{R_i}{\text{Max}[I_{\text{comp},R}]}\right],\quad i = 1,2,3,\cdots,p\,. \tag{7}$$

Third, the number of pixels having each red component value from 1 to D is counted. Finally, the normalized histogram of each red component value is transformed into the color component eigen vector of red component $\mathbf{E}_{\text{comp},R}$. The other eigen vectors of green $\mathbf{E}_{\text{comp},G}$ and blue $\mathbf{E}_{\text{comp},B}$ are given in much the same way as $\mathbf{E}_{\text{comp},R}$.

2.5 Eigen pattern of the color image

Let $\mathbf{E}_{\text{color}}$ be the eigen pattern of the color image. Then, $\mathbf{E}_{\text{color}}$ consists of six eigen vectors.

$$\mathbf{E}_{\text{color}} = [\mathbf{E}_{\text{int}}, \mathbf{E}_{\text{tone},R}, \mathbf{E}_{\text{tone},B}, \mathbf{E}_{\text{comp},R}, \mathbf{E}_{\text{comp},G}, \mathbf{E}_{\text{comp},B}]^T, \tag{8}$$

where T refers to a matrix transpose.

2.6 Eigen pattern of monochromatic image

At first, let I_{mono} be the monochromatic distribution. Then, the monochromatic distribution is given by

$$I_{\text{mono}} \in I_{\text{mono},i}\,,\quad i = 1,2,3,\cdots,p\,, \tag{9}$$

where $I_{\text{mono},i}$ is a monochromatic value of i-th pixel. Second, I_{mono} is normalized with the dynamic range D.

$$I_{\text{mono}}{}^{D} \in \text{Round}\left[D \times \frac{I_{\text{mono},i}}{\text{Max}[I_{\text{mono}}]}\right],\quad i = 1,2,3,\cdots,p\,. \tag{10}$$

Third, the number of pixels having each monochrome value from 1 to D is counted. Finally, the normalized histogram of each monochrome value is transformed into the eigen pattern of monochrome image $\mathbf{E}_{\text{mono}}$.

2.7 Application to dynamic image

A dynamic image is composed of some frame images. Thereby, we have to extract the eigen pattern from all of the frame images, and remove the phase information of dynamic image that same target object shifts different course. Thus, we extract the eigen pattern from the composite image that consists of all of the frame images. Since the eigen pattern removes spatial position on the screen, the eigen pattern of composite image removes the phase information of the dynamic image. Fig.1 shows animation images where the target object shifts to a different course and resulting eigen patterns. Both eigen patterns identical in Fig.1 (c). The eigen pattern of composite image removes spatial position on the screen as well as phase information of the dynamic image.

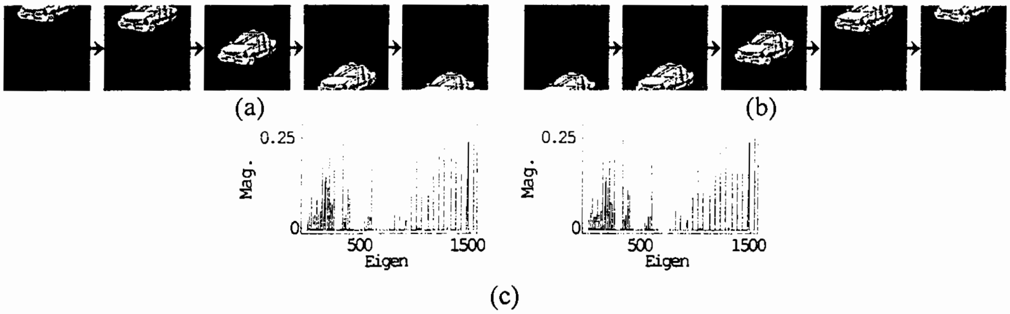

Fig.1. Eigen pattern of dynamic image
(a)Test image No.1 (b)Test image No.2
(c)Eigen patterns (left: test image No.1, right: test image No.2)

3 DYNAMIC IMAGE COGNITION

Dynamic image cognition is carried out using the eigen pattern as database. After evaluating the eigen patterns of given target images, database is composed by these eigen patterns. Solving a linear system of equations using the database makes it possible to cognize the test image. When the database consists of n-th eigen patterns of the image, a system matrix C is obtained by

$$C = [\mathbf{E}_1, \mathbf{E}_2, \mathbf{E}_3, \cdots, \mathbf{E}_n]. \tag{11}$$

The subscript of n in (11) refers to an eigen pattern of n-th image. Let $\mathbf{E}_X$ be the eigen pattern of test image for cognizing, then the system of equations is given by

$$\mathbf{E}_X = C \cdot \mathbf{X}. \tag{12}$$

Because of the system matrix C in (11) having n-th columns, the solution vector $\mathbf{X}$ becomes an n-th order vector. Since the number of elements of an eigen pattern is much greater than those of the database, it is possible to apply the conventional least squares technique [2], namely,

$$\mathbf{X} = [C^T C]^{-1} C^T \mathbf{E}_X. \tag{13}$$

When j-th element of the solution vector $\mathbf{X}$ in (12) is one and the other elements become zero, it is obvious that the test image is the same as the j-th database image. Consequently, the test image is cognized as the j-th database image.

4 EXAMPLES

4.1 Dynamic image cognition of monochromatic image

Fig.2 shows database images. Database images are four animation images that have the same background. Fig.3 shows test images. The route of the car is different from that of the database image. Both of images consist of five frame images.

At first, we computed all of the eigen patterns of the database images in Fig.2 as well as the test images in Fig.3. Second, we evaluated the solution vector $\mathbf{X}$ by means of least squares. Taking up the element having the maximum value in the solution vector $\mathbf{X}$ to each of the test images gives the results shown in Fig.4. The horizontal axis in the solution vector $\mathbf{X}$ corresponds to the database number in Fig.2. Even if monochrome image has not rich information compared with color image, we have succeeded in cognizing images as shown in Fig.4.

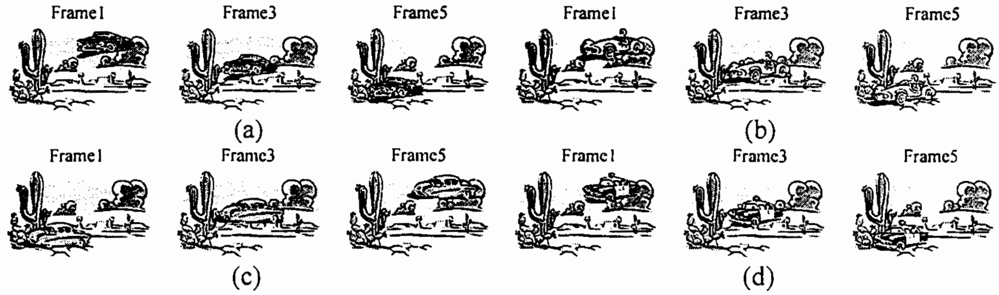

Fig.2. Database images
(a)Database No.1 (b)Database No.2
(c)Database No.3 (d)Database No.4

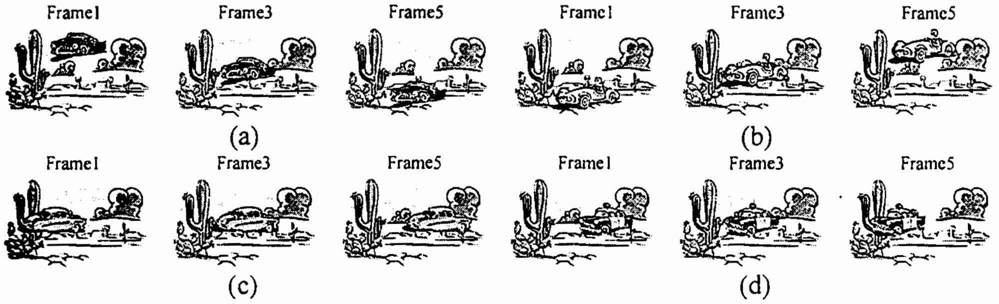

Fig.3. Test images
(a)Test No.1 (b)Test No.2
(c)Test No.3 (d)Test No.4

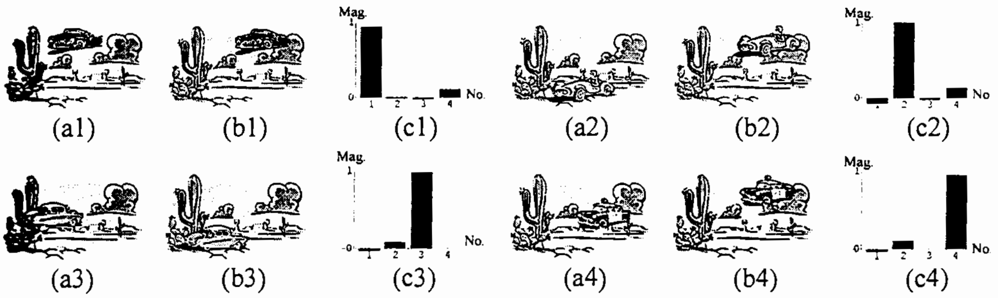

Fig.4. Cognized results
(a1)-(a4)Test images (Frame1) (b1)-(b4)Cognized images (Frame1)
(c1)-(c4)Solution vectors

4.2 Dynamic image cognition of color image

Fig.5 shows database images. Database images are five model trains that have been taken by a digital video camera. The train moves from right to left. Fig.6 presents test images. The train moves from left to right. Both images consist of thirty frame images. The cognized results presented in Fig.7 show that we have succeed in cognizing all of the test images. As a result, the eigen pattern removes the location, angle and size information on the screen, and extracts the essential characteristics of target digital image. Furthermore, it is possible to generate the eigen pattern having rich information obtained by multiple cameras. This may dramatically improve the cognition accuracy comparing single camera.

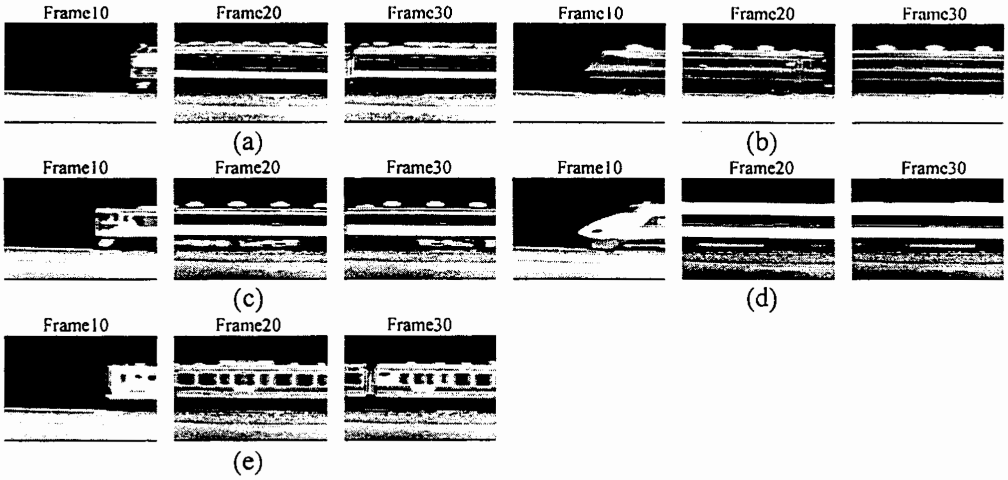

Fig.5. Database images
(a)Database No.1 (b)Database No.2 (c)Database No.3
(d)Database No.4 (e)Database No.5

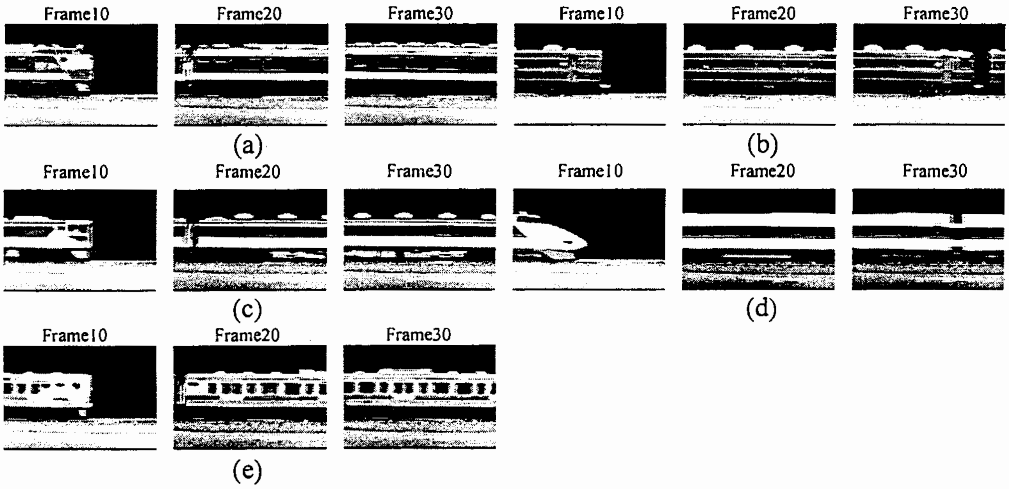

Fig.6. Test images
(a)Test No.1 (b)Test No.2 (c)Test No.3
(d)Test No.4 (e)Test No.5

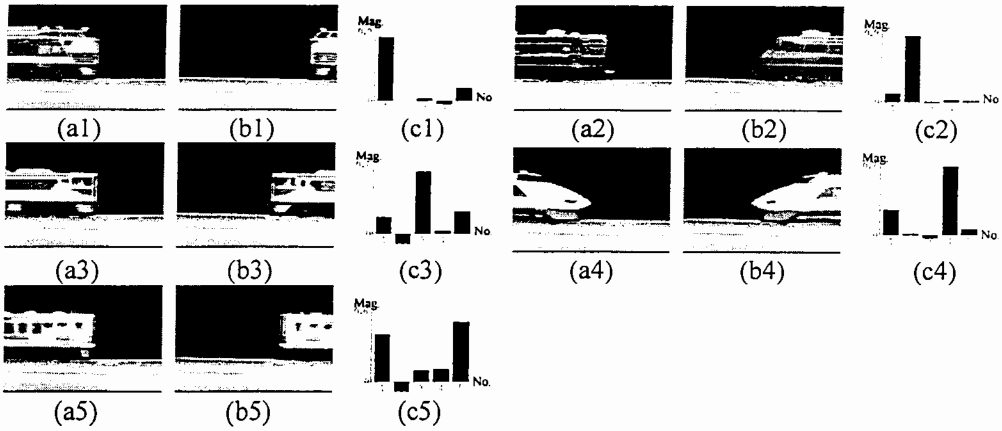

Fig.7. Cognized results
(a1)-(a5)Test images (Frame10) (b1)-(b5)Cognized images (Frame10)
(c1)-(c5)Solution vectors

5 CONCLUSIONS

In this paper, we have proposed the eigen pattern of visualized information in order to extract the essential characteristics of digital images. The eigen pattern removes the location, angle and size information on the screen. This eigen pattern methodology is generalized to the dynamic digital image. We have extracted the eigen pattern from the composite image that consists of all of the frame images in order to remove the phase information of dynamic image. As an example, we have applied our method to dynamic image cognition. Consequently, we have succeeded in cognizing color images as well as monochrome images exactly.

6 REFERENCES

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