IMAGE COGNITION BY MEANS OF INVERSE APPROACH

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Abstract. A new concept is introduced to extract the essential and distinct characteristics of images. The key idea is to introduce the eigen pattern, which consists of intensity, tone and color component of a digital image. A color graphics image on two-dimensional plane is represented by a set of the pixels containing the red, green and blue color information, and represented by geometrical arrangement of intensity, tone and color component. Thereby, color graphics images depend on their resolution and the spatial position on the screen. The eigen pattern removes the location, angle and size information on the screen, and extracts the essential characteristics of images. We apply the notion of eigen pattern to image cognition by means of inverse approach. As a result, we have succeeded in cognizing images exactly.

Keywords: Characteristics extraction, Image cognition Visualized information

INTRODUCTION

A lot of image processing technologies for computer use are developed based on human abilities like artificial intelligent (AI) and artificial neural network (ANN). It is difficult for computer image processing technologies to give the same ability as the human eyes.

“Visualized information”, called in this paper, is defined as cognizable information by the human eyes. The picture or image obtained by camera is one of the “visualized information”. Infrared and electron microscope are also capable of visualizing something that is directly invisible for the human eyes. Even if information is invisible, signal information makes it possible for the human eyes to cognize something by specific ways.

In case of the human brain, information coming from outside of someone 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 realize the human brain.

A color graphics image on two-dimensional plane is represented by a set of the pixels containing the red, green and blue color information, and represented by geometrical arrangement of intensity, tone and color component. Thereby, the color graphics images depend on their resolution and the spatial position on the screen. The key idea of characteristic extraction is to introduce the eigen pattern, which represents the essential characteristics of images independent of their resolution and the spatial position on the screen. As a result, our approaches have succeeded in cognizing images beyond the human eyes.

EIGEN PATTERN OF GRAPHICS IMAGES

Eigen pattern elements

The eigen pattern, proposed in this paper, is composed of eigen vectors of the three components, intensity, tone, 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 eigen pattern consists of the two eigen vectors. Since the tone is a ratio of color pixel, the tone eigen vectors can be given by two components of color image. The color component of eigen pattern is represented by three eigen vectors, red, green and blue eigen vectors. The elements of color component eigen vectors are given as the value of red, green and blue components of each pixel, respectively. Geometrical information is kept as the ratio of red, green and blue components.

Intensity eigen vector

At first, when we denote $I_{\mathrm{int},i}$ 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,

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

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},

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

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

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

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 0 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 E_{int} is obtained as normalized histogram of intensity value.

Tone eigen vector

The tone is a ratio of red, green and blue components of each pixel. Let $I_{\mathrm{Tone,R}}$ be the red component of tone distribution. Then, the tone distribution is given by

(4) $$I_{\text{Tone,R}} \in \frac{R_i}{I_{\text{int},i}}, \quad i = 1,2,\cdots,p.$$

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

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

Third, the number of pixels having each tone value from 0 to D is counted. Finally, normalized histogram of each tone value is transformed into the tone eigen vector of red component $E_{\text{Tone,R}}$. The other eigen vectors of green $E_{\text{Tone,G}}$ and blue $E_{\text{Tone,B}}$ are given in much the same way as Eqn. 5.

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. Geometrical information is kept as the ratio of red, green and blue components. 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

(6) $$I_{\text{Comp,R}} \in R_i, \quad i = 1,2,\cdots,p.$$

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

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

Third, the number of pixels having each red component value from 0 to D is counted. Finally, normalized histogram of each red component value is transformed into the color component eigen vector of red component $E_{\text{Comp,R}}$. The other eigen vectors of green $E_{\text{Comp,G}}$ and blue $E_{\text{Comp,B}}$ are given in much the same way as Eqn. 7.

Eigen pattern

Let a matrix E be the eigen pattern. Then, E consists of six eigen vectors.

(8) $$E = [E_{\text{int}}, E_{\text{Tone,R}}, E_{\text{Tone,G}}, E_{\text{Comp,R}}, E_{\text{Comp,G}}, E_{\text{Comp,B}}]^T.$$

Where T refers to a matrix transpose.

IMAGE COGNITION

Evaluation of correlation between eigen patterns by inverse approach

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 for 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

(9) $$C = [E_1, E_2, \cdots, E_n].$$

The subscript of n in Eqn. 9 refers to an eigen pattern of n^{th} image. Let $\boldsymbol{E}_X$ be the eigen pattern of test image for cognizing, then the system of equations is given by

$$\boldsymbol{E}_X = C \cdot \boldsymbol{X} \ . \tag{10}$$

Because of the system matrix C in Eqn. 9 having n^{th} columns, the solution vector $\boldsymbol{X}$ becomes n^{th} order vector. Since the number of elements of an eigen patter is much greater than those of the database, then it is possible to apply the conventional least squares, namely,

$$\boldsymbol{X} = [C^T C]^{-1} C^T \boldsymbol{E}_X \ . \tag{11}$$

When j-th element of solution vector $\boldsymbol{X}$ in Eqn. 10 is one and the other elements become zero, it is obvious that the test image is the same as the j-th database image. Namely, the test image is cognized as the j-th database image.

Test images

Fig. 1 shows test images and their eigen patterns. Test images are two animals, six human faces and eight artificial things such as a watch and a cellular phone. In this example, we have sixteen test images.

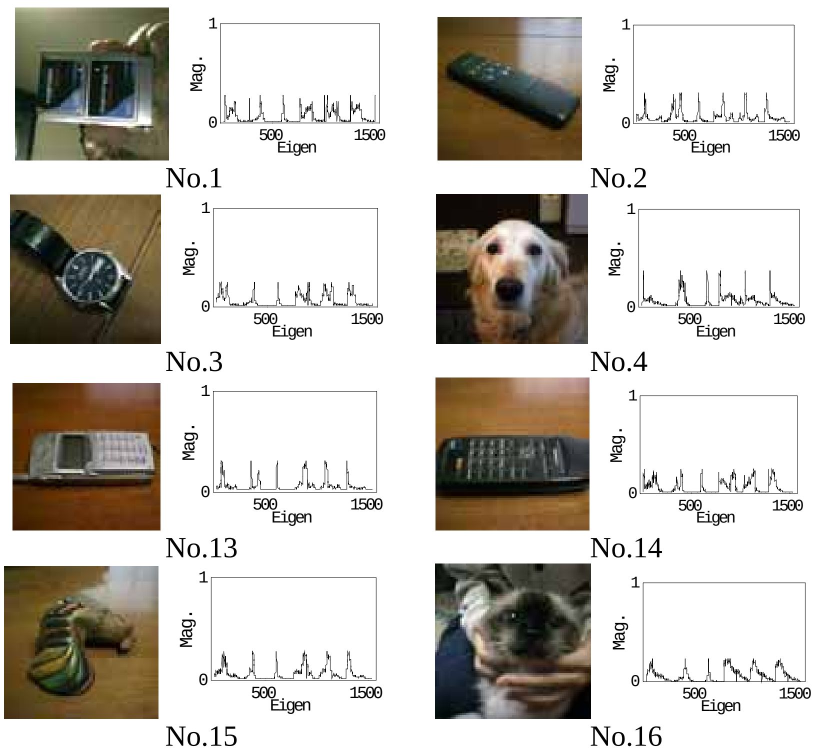

Figure 1. Test images

Database images

Fig. 2 shows database images and their eigen patterns. In this example, we have twenty images.

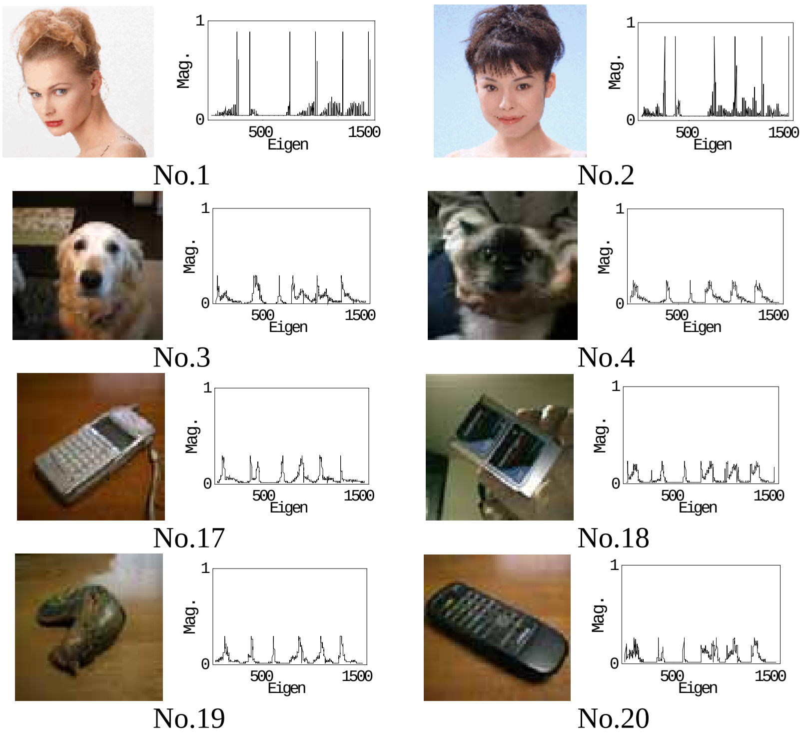

Figure 2. Database images

Result and Discussion

At first, we computed the all of eigen patterns of the test images in Fig. 1 as well as the database images in Fig. 2. Second, we evaluated the solution vector $\boldsymbol{X}$ by means of least squares. Taking up the element having maximum value in the solution vector $\boldsymbol{X}$ to each of the test images gives the results shown in Fig. 3. The horizontal axis in the solution vector $\boldsymbol{X}$ corresponds to database number in Fig. 2. The element having maximum value in the solution vector $\boldsymbol{X}$ is assumed to be cognized image, we have succeeded in cognizing all of the test images as shown in Fig. 3.

As a result, the eigen pattern removes the location, angle and size information on the screen, and extracts the essential characteristics of visualized information. 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.

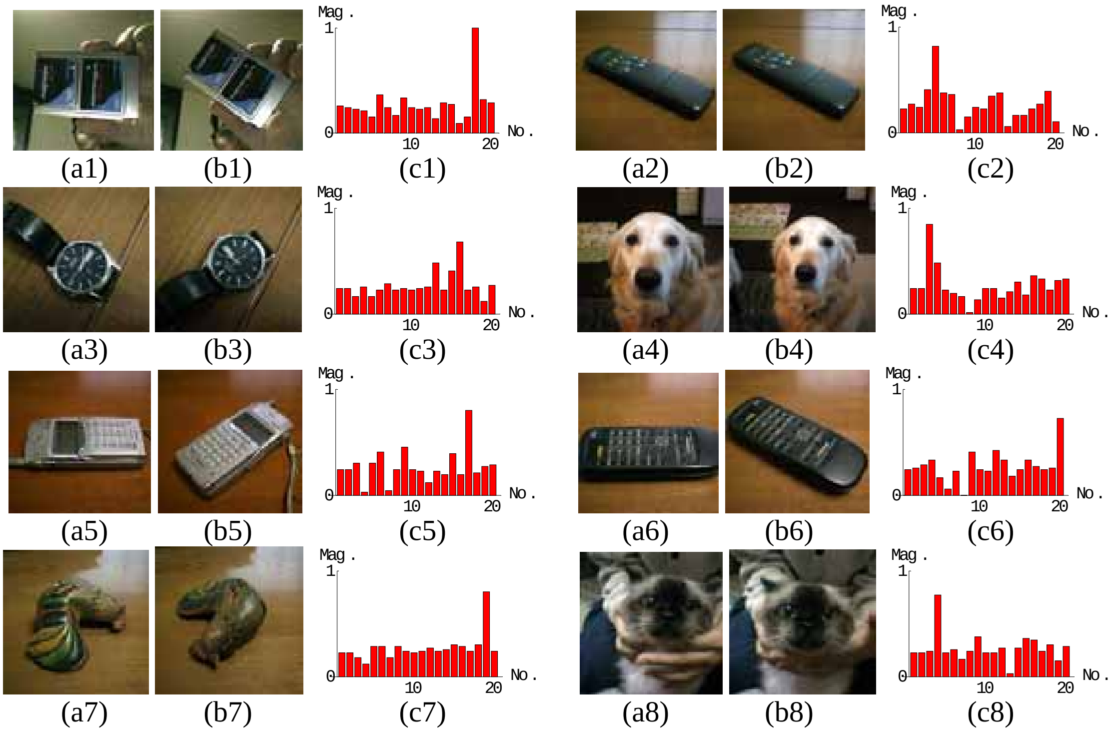

Figure 3. Cognized results
(a1)-(a8) Test images, (b1)-(b8) Cognized images, (c1)-(c8) Solution vectors

CONCLUSIONS

In this paper, we have proposed the eigen pattern of visualized information in order to extract the essential and distinct characteristics of images. The eigen pattern consists of intensity, tone and color component eigen vectors. Thereby, it removes the location, angle and size information on the screen, and makes it possible to extract the essential characteristics. As an example, we have applied our method to image cognition. Consequently, we have succeeded in cognizing images exactly.

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