Human Face Identification by Multi Scale MEGI

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Abstract

We proposed MEGI model for description and recognition of concave objects. The set of MEGI data consists of position vector and normal vector. No surface shape is needed, and the connectivity of each neighboring surface is not required. Using these features, elements unification procedure "multi scale MEGI" is proposed in this paper. Furthermore, Human face identification is also performed by multi scale MEGI.

1 Introduction

In order to recognize an object and to determine its attitude in space, it is necessary to have a method to represent the shape of the object. The extended Gaussian image description model (EGI) makes it easy to determine the attitude of a moving object in space [1]. It is independent of the position of the object EGI provides a unique description for a convex object, though precise information is limited. That is, no two convex objects have the same EGI. We proposed a new 3-D object description called MEGI (more extended Gaussian image) and a matching scale function called extended spherical correlation, which has the capability to distinguish not only convex objects, but also concave objects[4].

The recognition of MEGI needs only sets of surface data which consists of position vector and normal vector. No surface shape is needed, and the connectivity of each neighboring surface is not required. In this paper, we propose Multi scale MEGI using these features and human face identification by this method.

2 Object Recognition Using MEGI Model

2.1 MEGI Model

We proposed a new 3-D shape description method called more extended Gaussian image (MEGI), which includes information on surface positions, so it can describe not only convex but also concave objects[4].

The MEGI model consists of a set of position vectors X_i for surfaces originating from an object center and their normal vectors p_i (Figure 1). Each length of a normal vector also corresponds with surface area, as in the extended Gaussian image. This model is also shift-invariant since it is expressed by an object-oriented coordinate. Let $\mathbf{M}$ be a vector set which describes vectors of the MEGI element as follows:

$$\mathbf{M} = \{(\mathbf{X}_i, \mathbf{p}_i) | i \in \{0, 1, \cdots, m-1\}\} \quad (1)$$
$$\mathbf{X}_i, \mathbf{p}_i \in \mathbf{R}^3.$$

m indicates number of MEGI elements.

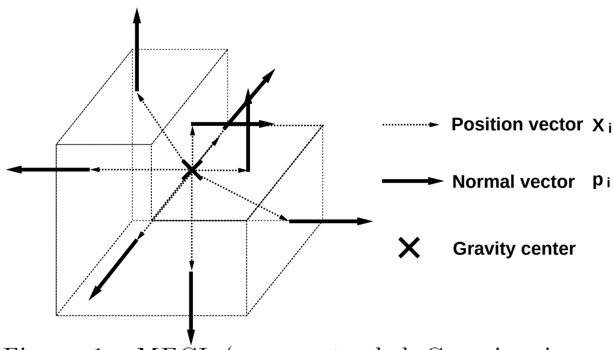


Figure 1: MEGI (more extended Gaussian image) model

2.2 Extended Spherical Correlation

Let $\mathbf{X}$ and $\mathbf{Y}$ be sets of n-dimensional unit vectors and let the elements be $\mathbf{X} = \{\mathbf{X}_0, \mathbf{X}_1, \ldots, \mathbf{X}_{m-1}\}$, $\mathbf{Y} = \{\mathbf{Y}_0, \mathbf{Y}_1, \ldots, \mathbf{Y}_{m-1}\}$ $(\|\mathbf{X}_i\| = \|\mathbf{Y}_i\| = 1)$.

We proposed a new coefficient for recognizing 3-D objects with the MEGI model, which is an extension of the spherical correlation coefficients proposed by Fisher and Lee[2]. The definition is as follows.

$$EC = {m_1}^{\alpha} * {m_2}^{\beta} \quad (2)$$

$$m_1 = \frac{1}{2}\left(\frac{\det\left\{\sum_i \mathbf{p}_i\mathbf{q}_i'\right\}}{\sqrt{\det\left\{\sum_i \mathbf{p}_i\mathbf{p}_i'\right\}\det\left\{\sum_i \mathbf{q}_i\mathbf{q}_i'\right\}}}+1\right) \quad (3)$$

$$m_2 = \frac{1}{(\gamma|\log(S)|+1)d_q} \sum_i\left(1-\frac{\left|\sum_{j\in d(i)}\|\mathbf{p}_j\| - \frac{\|\mathbf{q}_i\|}{S}\right|}{\sum_{j\in d(i)}\|\mathbf{p}_j\| + \frac{\|\mathbf{q}_i\|}{S}}\right) \quad (4)$$

$$S = \frac{\|\mathbf{q}_0\|}{\sum_{j\in d(0)}\|\mathbf{p}_j\|}, \quad (5)$$

where $\mathbf{p}_i$ and $\mathbf{q}_i$ are the normal vectors for object A and object B which calculate the correlations, d_q denotes the number of vectors $\mathbf{q}$, α, β and γ are constant values, " $'$ " in the equations denotes the transpose of the matrix, and $d(i)$ denotes the set of the vector number of $\mathbf{p}$ which corresponds to $\mathbf{q}_i$.

Equation (3) is a function having a range ($0 \leq m_1 \leq 1$) which is derived from the spherical correlation coefficients by Fisher and Lee. Equation (4) describes the difference in volume between the two objects. α,β and γ are the constant values whose parameters control the behavior of the coefficient. The parameter α sets the influence of the original spherical correlation, the parameter β controls the influence of the difference between surface areas, and the parameter γ controls the influence of the volume difference between objects for the extended spherical correlation.

The value calculated by equation (3) is rotational invariant since Fisher's spherical correlation coefficients are rotational invariant. m_2 derived from equation (4) is a scalar value. Therefore the extended spherical correlation defined by equation (2) is also rotational invariant. Hence using the MEGI model proposed in **2.1** and the extended spherical correction, we can estimate the matching score which is shift and rotational invariant.

2.3 Matching Algorithm Using MEGI

In order to calculate the EC which was defined in **2.2**, the correspondence of each MEGI element (a set of position vectors and normal vectors) must be known. But this correspondence is unknown for general 3-D objects. Therefore a correspondence procedure for MEGI elements of two objects must be performed in some way. We proposed the correspondence determination function (CF)[4]

3 Multi Scale MEGI

In the proposed matching methods using an extended spherical correlation coefficients and MEGI, miss-correspondence between two object have a serious influence on calculation of EC. In the correspondence procedure, miss correspondence may sometimes be occurred by the following reasons.

- If single surface is divided into a few surfaces through the inference of noise, the calculated correlation will be changed drastically.
- In MEGI, a curved surface is expressed as a set of small surfaces in which position vectors and normal vectors are slightly changed respectively. As a result of this description method, number of surfaces and area of each small surface that describes a curved surface will be different between objects A and object B. Same as mentioned above, the calculated correlation will be changed drastically.

To solve these problems, we proposed a new multi scale matching method called multi scale MEGI.

The set of MEGI data consists of position vector and normal vector. No surface shape is needed, and the connectivity of each neighboring surface is not required. Using these features, elements unification (decreasing resolution) procedure is proposed as follows.

1. Let scale factor s, unification threshold of normal vector TH_{normal} and unification threshold of position vector $TH_{position}$ set to 0 respectively.
2. Originally, a set of element E^0 which has a set of position vectors $\mathbf{X}$ and corresponded set of normal vectors $\mathbf{p}$ is constructed using three neighboring sampled range data.
3. $s \leftarrow s+1$, $TH_{normal} \leftarrow TH_{normal}+\Delta_1$, $TH_{position} \leftarrow TH_{position}+\Delta_2$, Δ_1 and Δ_2 are multi scale step of normal and position vectors respectively.
4. Select one element E_i^s which has two parameters normal vector $\mathbf{p}_i^s$ and position vector $\mathbf{X}_i^s$, in E^s by the order of element size.
   - Select all elements which satisfies following two conditions at once. A set of selected element including E_i^s denotes G_i^s. The position and normal vector of unified elements are recalculated from equations (6) and (7).
     (a) An angle between $\mathbf{p}_i^s$ and normal vector of selected element is within TH_{normal}.
     (a) Distance between $\mathbf{X}_i^s$ and position vector of selected element is within $TH_{position}$.

$$\mathbf{X}_i^{s+1} = \frac{\sum_{j\in G_i^s}\|\mathbf{p}_j^s\|\mathbf{X}_j^s}{\sum_{j\in G_i^s}\|\mathbf{p}_j^s\|} \quad (6)$$

$$\mathbf{p}_i^{s+1} = \sum_{j\in G_i^s}\|\mathbf{p}_j^s\|\frac{\sum\mathbf{p}_j^s}{\|\sum\mathbf{p}_j^s\|} \quad (7)$$

- If No more elements are unified, then goto 3.

An extended spherical correlation coefficients of multi scale MEGI is defined as maximum EC defined by equation (2) as changing multi scale factor s of object A and object B independently.

3.1 Human face matching using multi scale MEGI

The experiment using multi scale MEGI is performed with the range data of human full face data (25 faces) produced by the National Research Council Canada(NRCC)[3]. Hair part of each full face data is eliminated. Multi scale step Δ_1 is set at 5 degree, Δ_2 is set at 10% length compared with maximum normal size of position vector in human full face data and four multi scale step data is constructed for calculating the extended spherical correlation coefficient of multi scale MEGI. Figure 8 shows extended spherical correlation coefficients of multi scale MEGI between FACE26 and other full face data including FACE26. It is difficult to determine the similarity scale of human face, but these matching result shows the possibility of multi scale MEGI for identification and recognition of curved 3-D object such as human face.

Furthermore, we simulated partial matching between full face data and partial face data which includes some hidden area. Table 5 shows matching result between partial face data FACE6 and FACE12 and 25 full face data. These result shows two partial face data FACE6 and FACE12 matched their original full face data, although extended spherical correlation coefficient becomes slightly low. So it is possible to recognize the partial objects with multi scale MEGI and extended spherical correlation coefficient.

4 Conclusions

We proposed multi scale MEGI which has a feature of multi scale description, and experiment using human face range data are also performed.

The proposed description Multi scale MEGI is a simple model which has no form information and adjacency relationships for surfaces. In spite of this simplicity, the experimental result shows that the correlation coefficient represents the similarity between objects. Multi scale MEGI are based on plane based matching. Therefore these two MEGI matching method applies curved 3D objects, Some strange matching result is given compared from human subjective perspective result. Presently, we have a plan to extract the description of MEGI which can applies curved 3D objects.

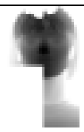
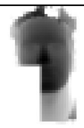
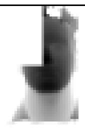
	 FACE6	 FACE6	 FACE12	 FACE12
1	0.33	0.40	0.42	0.34
2	0.43	0.48	0.43	0.50
3	0.37	0.49	0.36	0.37
5	0.26	0.44	0.44	0.49
6	0.74	0.52	0.44	0.34
7	0.24	0.28	0.36	0.44
8	0.36	0.36	0.46	0.36
9	0.32	0.32	0.36	0.34
10	0.32	0.29	0.50	0.34
12	0.41	0.28	0.95	0.73
14	0.50	0.41	0.29	0.27
16	0.36	0.41	0.28	0.29
18	0.23	0.33	0.25	0.29
20	0.36	0.41	0.43	0.48
22	0.31	0.40	0.61	0.52
24	0.35	0.40	0.57	0.47
26	0.28	0.41	0.40	0.46
28	0.36	0.23	0.36	0.43
30	0.31	0.40	0.29	0.32
31	0.27	0.27	0.69	0.63
32	0.41	0.33	0.59	0.52
33	0.24	0.26	0.41	0.26
34	0.29	0.44	0.47	0.53
35	0.31	0.31	0.38	0.61
36	0.29	0.46	0.33	0.44

Table 1: Result of human face identification between full face data and partial face data. Left row describes the number of full face data.

ACKNOWLEDGMENT

The authors are grateful to former current students K. Tsuchiya ,T. Okamoto and J. Funabashi.

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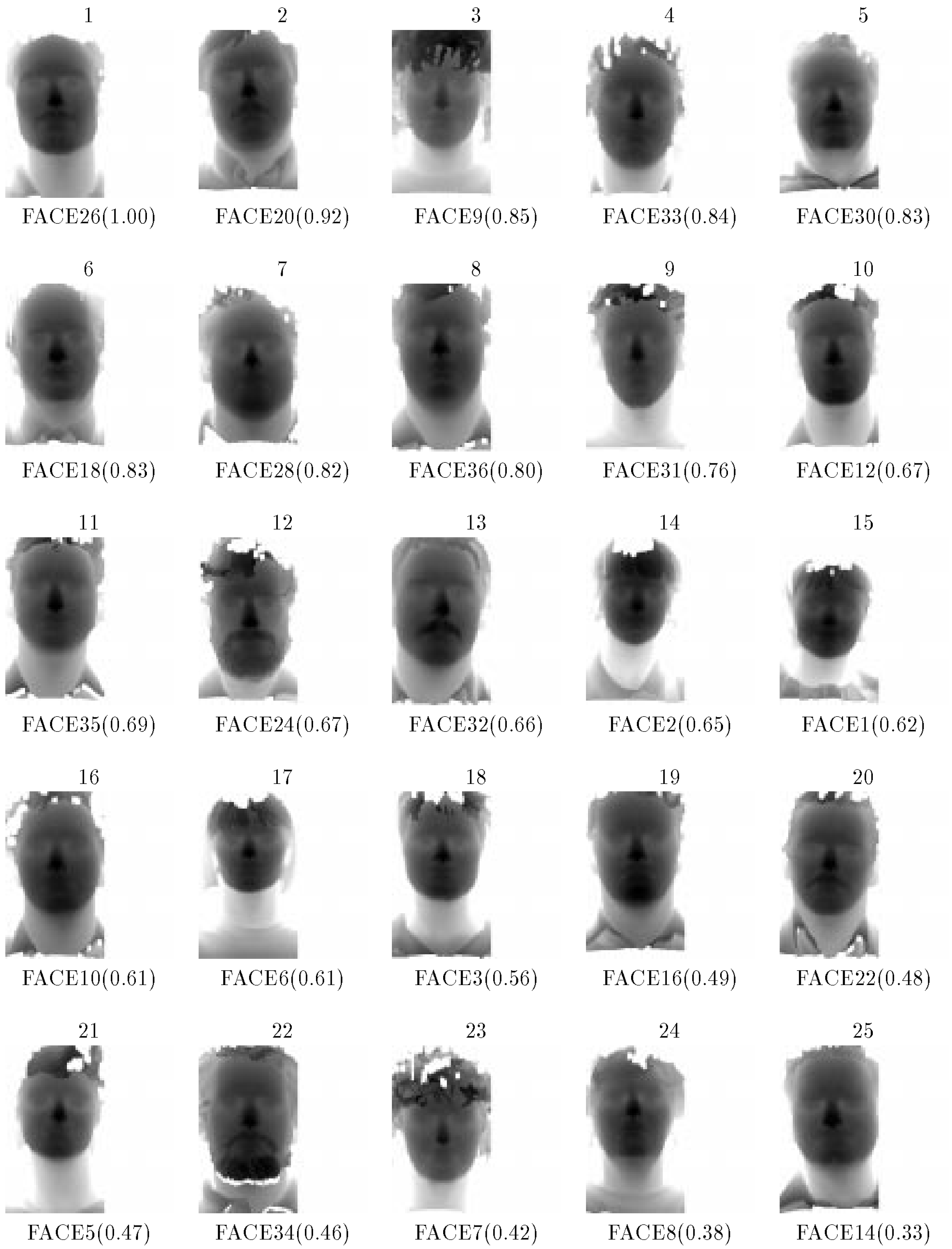

Figure 2: Results of human face identification. The number on each full face data describes the identification order. The number within parenthesis is extended spherical correlation coefficient against FACE26.