— Original Article —

**Face-to-Face Video Superimposition Using
Three Dimensional Physiognomic Analysis**

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This face-to-face video superimposition system consists of two main pieces of equipment, namely a 3D physiognomic measurement apparatus for obtaining 3D image data of face, and a 3D analysis apparatus for comparing the 3D facial image with facial photographs video superimposition. The 3D physiognomic measurement apparatus is composed of a detector comprised of two laser scanner devices and two CCD cameras, an image encoder interfaced to a computer, and two TV monitors. The 3D analysis apparatus comprises of the following five parts : a host computer, an image processing unit, a CCD camera for inputting facial photographs of a perpetrator, a video image mixing unit and a TV monitor. The 3D surface morphology of a suspect face is measured with the detector using three representative parameters of the facial surface, that is, the illumination, brightness and depth data. The parameters are measured and then stored on the floppy disk. The 3D facial image of the suspect is superimposed on the facial photograph of the perpetrator on the monitor using the 3D analysis apparatus. In order to assess the reliability of the facial photographic identification with this system, the face-to-face superimposition was experimentally investigated. An oblique facial photograph of a target person was compared to the 3D facial image of the target person and other 19 examinees. The 2D facial photograph of the target person revealed a good match with the 3D facial image of one of the subjects, giving a positive identification. This system will be a useful tool for forensic photographic comparison and will prove very effective in court because the video superimposition of two faces can be performed under the same facial orientation.

Key words : Forensic anthropology, Facial photographic identification, 3D facial image, Video superimposition

Introduction

Recently, facial photograph comparison in criminal cases has become increasingly important due to the widespread use of security cameras, so that, the reliability of the identification of facial photographs is becoming a serious concern in forensic physiognomy. Facial photograph comparison is routinely performed for the video and photographic identification in bank robberies, passport inspection for illegal immigrants, infrared photographic identification of illegal vehicles and so on. From the scientific aspect, Kerley¹⁾ was probably the first to present a paper on the subject by comparing the newspaper photograph of a face in a crowd with that of a known person. Facial photographic identification is generally attempted using three methods : morphological comparison of facial features, photographic anthropometry and face-to-face video superimposition^{2),3)}. The morphological comparison of facial photographs is carried out based on the morphological classification of facial components such

as facial types, eyebrows, eyes, nose, lips and ears. Several classification system on facial components have been published³⁻⁵⁾. The photographic anthropometry is quantitative analysis based on indices calculated from measurements of facial dimensions. Catterick⁶⁾ has experimentally examined the value of using measurements from photographs for facial comparisons. He has stated that facial measurements would only form part of a comparison procedure, and that other factors such as hair style and ear shape should also be considered when trying to attempt facial comparisons.

Over the last two decades, the cranio-facial video superimposition method has been used for skull identification⁷⁻¹³⁾. The video superimposition technique has also been applied to facial photographic identification¹⁴⁻¹⁶⁾. This latter technique however requires that the facial photograph is taken in exactly the same orientation as the two dimensional (2D) facial image at the crime scene. To solve this problem, we attempted to build a new video superimposition system using three dimensional (3D) imaging system for identifying facial photographs.

Fig. 1 Schema of the video superimposition system consisting of the 3D physiognomic measurement apparatus for obtaining 3D image data of a suspect face (A) and the 3D analysis apparatus for comparing the 3D facial image of the suspect with a facial photograph of a perpetrator.

Constitution of Equipment

This face-to-face video superimposition system consists of two main pieces of equipment, namely a 3D physiognomic measurement apparatus for obtaining 3D image data of face, and a 3D analysis apparatus for comparing the 3D facial image with facial photographs (Fig. 1).

The 3D physiognomic measurement apparatus is composed of a detector for measuring facial surface (Voxelan NKV-300S, Hmano Engineering Inc., Japan), an image encoder interfaced to an NEC PC9821-An/U2 (240 Mb hard disk) and two 12-in. TV monitors (Fig. 1A). The detector consists of two laser scanner devices and two CCD cameras positioned at the left and right hand sides of the apparatus. Two lights are also set at both sides of the detector.

3D analysis apparatus consists of a proprietary software (MEDIC Engineering, Japan) and associated hardware, consisting of an image processing unit connected to an NEC PC9821-An/U8W host computer (340 Mb hard disk), a CCD camera for inputting facial photographs of a perpetrator (Fujinon TV Zoom Lens 12.5 – 75mm), a video image mixing unit and a 14-in. high-resolution TV monitor (Fig. 1B). To record data, a 128 Mb 3.5 inches MO disk drive, a videotape recorder, a film recorder and a color printer are attached to this system.

Method of Operation

3D physiognomic measurement

The morphology of the suspect's face is measured with the detector. At first the illumination images of the face is taken with the two CCD cameras under the light-up condition (Fig. 2). In the same facial position, a spot of light produced from semiconductor laser (5mW, 670nm) is projected onto the face under the darkness condition. The CCD camera then searches for this point and records its position. The laser scanner is able to record 76,800 surface coordinates with a resolution of 0.5mm in 10 seconds. The measurement area of the detector is 300mm² and its depth is ± 100 mm. The angular width taken with the two CCD cameras is 220°, giving a sufficiently large measurement range to enable data for the ear shape to be included (Fig. 3). The 3D image data of the face is derived from the digitally recorded video signals by using the image encoder. The three parameters, namely the illumination, brightness and depth data are computed (Fig. 4). The brightness data is derived from the difference between the highest brightness and the lowest brightness on the facial surface. The depth data of the face is determined using triangulation theory. In this system, the illumination data is used for compositing 3D facial image because the illumination data is more life-like resemblance compared to the brightness data. The illumination and

Fig. 2 The 3D surface morphology of a face is measured with the detector. The illumination data of the face is first obtained with two CCD cameras (1) under the light-up condition. 2: Laser scanner devices, 3: Illumination lights.

Fig. 3 Illustration showing a measuring area of a face by 3D physiognomic measurement apparatus. A wide field of facial view can be covered with two CCD cameras.

depth data of the face are stored in a floppy disk (about 960 Kb per person) and transferred to the 3D analysis apparatus.

3D facial image

The oblique facial images for the left and right cameras are first reproduced from the illumination and depth data recorded on the floppy disk by 3D analysis apparatus (Fig. 5). The 3D facial image is then generated from the two oblique facial images (Fig. 6A). The 3D facial

image has cylindrical coordinates and is able to move in any direction under the framework mode. A reference line is provided by setting a vertical line on the midline of the face, together with two horizontal lines set on the level of the ectocanthion and the lowest level of the nose (Fig. 6B). A fine computer graphic (CG) image of the face is then obtained by mapping the illumination data onto the framework image. In this system, any perspective distortion of the 3D facial image can be electronically corrected by inputting the distance between a security camera and a face of perpetrator (Fig. 7).

Video superimposition

To make the comparison between a 3D facial image of a suspect and a facial photograph of a perpetrator, the 2D facial image of the perpetrator is taken with the CCD camera and reproduced on the monitor through the video image mixing unit (Fig. 8A). The 3D facial image of the suspect is superimposed on the 2D facial image of the perpetrator. The superimposed image is then adjusted to match the orientation of the scene of crime image under the framework mode. The size of 2D facial image is adjusted to that of the 3D facial image using the zoom mechanism of the CCD camera. A fade-out mode of the video image mixing unit is helpful for adjusting both images. After the determination of the orientation and size of both images, the framework mode of 3D facial image is converted to the fine CG image (Fig. 8B). The fade-out or wipe mode of the video image mixing unit, especially the latter facilitates the comparison between 2D and 3D facial images (Fig. 8C,D). The process of face-

Fig. 4 The illumination data of a face for the right camera (R) and the depth data of the face for the left camera (L).

Fig. 5 Facial images composed of the illumination and depth data for the left and right cameras.

to-face superimposition on the monitor is recorded on the videotape. The image of each superimposition step is also outputted with the film recorder or color printer.

Experimental Study

Samples and Examination Items

In order to assess the reliability of the facial photographic identification with this system, face-to-face video superimposition was experimentally performed. An oblique facial photograph of one Japanese male, which was taken with an Nikon F4 (Lens 50mm, f2.8) at a

distance of 5 meters, was used as the target subject (Fig. 9). The quality of the facial photograph is the same grade as photographs that have been submitted in actual case work. The 3D facial data of 20 Japanese male examinees including the target person were obtained using the 3D physiognomic measurement apparatus. The facial photograph (2D facial image) of the target person was each compared with each of the 3D facial images of the 20 examinees using the 3D analysis apparatus.

In the present study, 20 examination items were used for assessment of anatomical consistency between 2D and 3D facial images (Table 1).

Fig. 6 The 3D facial Image generated from facial images shown in Fig. 5 (A) and its framework mode (B). The vertical line (1) is set on the midline, and two horizontal lines are set on the level of the ectocanthion (2) and the lowest level of the nose (3).

Fig. 7 The difference of the 3D facial images according to the distance between the camera and object. A : 50cm, B : 500cm. In the case of short distance, the facial image is slender and the protrusion of the ears is weak.

Results

The 2D facial image of the target person revealed a good match with the 3D facial image of No.9 examinee in all examined items (Table 2, Fig. 10). The 3D facial images of other 19 examinees were not consistent with 2D facial image of the target person (Table 2). Although No.7 examinee had 10 matching items, the 3D facial image of No.7 examinee was easily distinguished from the 2D facial image of the target person (Table 2, Fig. 11). Consequently, in this experimental study, the facial photograph of the target person was positively identified

as No.9 examinee. This result suggests that this video superimposition system is reliable and useful for forensic photographic identification.

Discussion

Facial photographic comparison is carried out to determine whether or not a facial image at the scene of a crime is that of a suspect. The morphological comparison of facial components is mainly used for identifying the facial image in actual cases. In some cases

Fig. 8 Face-to-face superimposition showing comparison between faces of the same person. A : 2D facial photograph, B : Total mixing image of the 2D facial image (Fig. 8A) and the 3D facial image (Fig. 6), C : Vertical wipe image, D : Horizontal wipe image. These superimposition images reveal a good match of the outline of face and facial components such as the eyebrows, eyes, nose, lips and ears.

in which the two facial images of a perpetrator and suspect are taken from almost same angle, the indices based on facial measurements were also used for comparing both images. Catterick⁶⁾ applied the image processing system to recognize passport-size facial photographs by two indices calculated from three facial measurements of the midline of the face. According to him, 72% of the passport quality photograph pairs and 66% of the magazine photograph pairs were distinguishable in 351 pair-wise permutations of 27 facial photographs. These results showed that the discriminating power based on facial measurements would be limited. In order to directly assess the two facial images, the video superimposition technique has been applied to the facial image comparison¹⁴⁻¹⁶⁾. Majumdar and Shinha¹⁴⁾ experimentally investigated the efficiency of a computer-controlled video camera superimposition for comparing

front facial views. They stated that front view perspective of facial photographs taken within 30° camera angle showed a breaking projective symmetry sufficiently small to be considered for accurate comparison. Maples and Austin¹⁵⁾ reported that the video superimposition technique was useful in cases when the quality of the perpetrator photograph was adequate for meaningful comparisons and when the suspect could be photographed by laboratory personnel at the correct position relative to the camera. Vanezis and Brierley¹⁶⁾ used the video superimposition technique to identify the facial image of suspects in 46 criminal cases. According to them, direct comparisons could be made in 36 cases including 20 major viewpoint discrepancy cases. The examiner should therefore consider any discrepancy in angulation when deciding whether the dissimilarity between facial components is real, or due

Fig. 9 Facial photograph of the target person.

Table 1 Examination items for assessment of anatomical consistency between 2D and 3D facial images

<u>A. Facial outline</u>	<u>D. Nose</u>
1. Left side	1. Nasal dorsum
2. Right side	2. Nasal tip
<u>B. Eyebrows</u>	3. Left nasal wing
1. Left medial edge	4. Right nasal wing
2. Right medial edge	5. Upper edge of nostril
3. Left lateral edge	<u>E. Lips</u>
4. Left lateral edge	1. Oral slit
<u>C. Eyes</u>	2. Left cheilion
1. Left entocanthion	3. Right cheilion
2. Right entocanthion	<u>F. Ears</u>
3. Left ectocanthion	1. Helix
4. Right ectocanthion	2. Ear lobe

to differences in orientation. The face-to-face video superimposition system using 3D measurement apparatus was developed to solve the problems described above. In this system, the wide facial view including ears could be accomplished with two CCD cameras. This is advantageous for the comparison of two facial images because the ear is generally considered to be an important component for personal identification. Vanezis and Brierley¹⁶⁾ also reported that the ear was a significant feature in 6 out of 11 positive identification cases. The upper border of the head was not reproduced on the monitor in this system

because the representative data of dark head hair could not be obtained by the laser scanner device. Of course, the outline between the head hair and face was clearly reproduced. It is reasonable to suppose that the lack of data on the head hair region does not exert a harmful influence on facial image comparison. Using the fade-out mechanism of this system, the 3D facial image could be easily adjusted to the orientation of the 2D facial image under the framework mode. This process may be more precise and practical compared with the video superimposition system developed by Majumdar and Sinha¹⁴⁾. However, Vanezis and Brierley¹⁶⁾ described that reliance should not be placed solely on fading between two images to assess a morphological match, because of the well established observation that the human eye may be led from one image to another, blending the two together, and thus be left with the impression that there is a good match. As shown in the results, the wipe mode was more suitable for detailed examinations for matching between two facial images because the components of each image could be clearly observed at the leading edge of the wipe. Vanezis and Brierley¹⁶⁾ also stated that close examination for matching should be carried out with the aid of various wipes. The perspective distortion based on the distance between the face and camera is one of the important factors to the facial image comparison. In this system, the perspective distortion of the 3D facial image was electronically corrected by taking into account the distance between the face and camera in a scene of crime. Moreover, instead of the brightness data, the illumination data was used to generate a fine facial image. These procedures may improve in the accuracy of the facial image identification.

Majumdar and Sinha¹⁴⁾ experimentally demonstrated the identification of a disguised human face by the video superimposition technique. They selected seven landmarks (inner and outer corners of both eyes, outer corners of lips and the subnasal point) as an assessment point for comparing the two facial images. In the present experimental study, 20 anatomical landmarks were used for facial image comparisons. The 3D facial image of No. 9 examinee (the target person) exhibited a good match with the facial photograph of the target person in 20 examination items. Thus, it was ascertained that they were of the same person.

In conclusion, this face-to-face video superimposition system will be a useful tool for forensic photographic identification and will prove very effective in court. In order to apply this system to the case work, additional factors such as expressions of face, disguised faces and quality of photograph or video at the crime scene need to be investigated.

Fig. 10 Face-to-face superimposition of the target person (Fig. 9) and No.9 examinee. A : Total mixing of the 2D facial image of the target person and the 3D framework image of No.9 examinee showing a good match of the facial outline. B : 3D facial image of No.9 examinee obtained by mapping the illumination data onto the framework image (Fig.10A). C : Total mixing image of the 2D facial image of the target person and the 3D facial image (Fig. 10B). D : Vertical wipe image. In these superimposition images, the shape and position of each component in 3D facial image are well consistent with those in 2D facial image.

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Fig. 11 Face-to-face superimposition of the target person (Fig. 9) and No.7 examinee. A : Total mixing image of the 2D facial image of the target person and the 3D facial image of No.7 examinee showing the inconsistency in the eyebrows and right ear. B : Vertical wipe image. Although the right entocanthion and oral slit reveal a good match, the medial edge of right eyebrow is inconsistent each other.

Table. 2 Assessment of anatomical consistency between 2D and 3D facial images
(Target person : No. 9)

Examination items		Examinee number																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Outline	A1				+	+		+	+	+				+	+			+	+		
	A2									+											
Eyebrows	B1									+											
	B2			+						+											
	B3									+											
	B4									+	+	+									
Eyes	C1	+	+	+				+	+	+	+	+	+	+	+	+		+	+		+
	C2	+	+	+				+		+			+		+	+		+			+
	C3			+	+			+	+	+			+	+		+		+	+		
	C4				+			+		+			+		+	+		+	+	+	+
Nose	D1									+				+	+					+	
	D2		+					+	+	+	+									+	
	D3									+											
	D4			+				+	+	+				+				+		+	
	D5									+											
Lips	E1							+		+					+						
	E2							+		+					+		+	+			
	E3			+				+		+					+			+			
Ears	F1									+				+							
	F2									+											

+ : consistent , - : not examined

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