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ORIGINAL ARTICLE

Preliminary Study of Craniofacial Superimposition by Mathematics Programming in a Thai Population

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ABSTRAK

Superimposisi kraniofasial digunakan dalam kes yang telah menemui tengkorak manusia yang tidak dikenali. Tujuan penyelidikan ini adalah untuk mengkaji dan membangunkan program superimposisi kraniofasial dengan menggunakan program matematik untuk meningkatkan kredibiliti superimposisi kraniofasial di Thailand. Kajian ini dijalankan pada 20 tengkorak, yang terdiri daripada 10 tengkorak lelaki dan 10 tengkorak perempuan. Semua sampel diambil dari Pusat Penyelidikan Osteologi Forensik (FORC), Fakulti Perubatan, Universiti Chiang Mai. Fotograf tengkorak dan wajah si mati diambil daripada posisi muka depan. Posisi tindanan fotograf tengkorak sebenar dan fotograf wajah dibandingkan dengan fotograf tengkorak rawak dan fotograf wajah. Kesamaan pencapaian dari tepi fotograf yang dibandingkan dengan ciri penting dengan program matematik, di mana penyelidik menggunakan fungsi dan prinsip matematik matriks dan logik. Dalam setiap eksperimen, keputusan antara tengkorak muka sebenar dan tengkorak muka rawak muka dicatat dalam bentuk kualitatif. Keputusan menunjukkan bahawa program yang digunakan dapat menilai dengan tepat kesamaan 19 kes daripada 20 kes. Superimposisi kraniofasial dapat menjimatkan kos pengujian DNA dan boleh digunakan dalam pemeriksaan penyaringan awal. Penyelidikan ini akan dapat mempermudahkan, mempercepatkan, meningkatkan kebolehpercayaan dan menjimatkan kos proses pengenalpastian.

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Kata kunci: matematik, sains forensik, superimposisi kraniofasial, Thailand

ABSTRACT

Craniofacial superimposition are used in cases where one has found an unknown human skull. The purpose of this research was to develop craniofacial superimposition by applying mathematical programme to increase the credibility of craniofacial superimposition in Thailand. To calculate the overlay position of face-real skull photo and face photo from the same owner were compared to the face-randomised skull photo and face photo. This study was carried out on a sample of 20 skulls, divided into 10 male skulls and 10 female skulls. All samples of bones were taken from the Forensic Osteology Research Center (FORC), Faculty of Medicine, Chiang Mai University. Skull and face photography of the deceased took only the front-straight face position. The similarity was found out from edges of them that compared at important points with the mathematical programme, in which the researchers applied functions and mathematical principles of matrix and logical. In each individual experiment between face-real skull and face-randomised skull, the results were recorded and explained in the form of qualitative experiments. From the experiment found that the used programme can be able to correctly assess the similarity are 19 cases of 20 cases. Craniofacial superimposition can save the budget of DNA testing and can be screening for the initial assumption. This research will be able to facilitate, work faster, more reliable and save budget in the identifying process.

Keywords: craniofacial superimposition, forensic science, mathematics, Thailand

INTRODUCTION

Nowadays, the identification of a corpse to confirm death is the most important before leading to the legal process. There are many ways to identify, such as DNA analysis, iris analysis, fingerprints analysis and etc. These mentioned methods can be done in the case that the person is known and then confirm the assumption. But craniofacial superimposition is used in unknown skull cases and provides a clue regarding the identity of a missing person creating a basis for making a decision. The skull is then sent for verification of the identification.

According to the research, the development of craniofacial superimposition is more reliable by applying computer programmes and mathematical principles in many countries. Such research describes the computer programmes used to compare important points on the face (Campomanes-Alvarez et al. 2014), the 2D-3D computer-aided non-automatic superimposition techniques (Campomanes-Alvarez et al. 2018) and modeling skull-face correspondence

for craniofacial superimposition-based identification (Gaudio et al. 2016). These studies have high precision ability in craniofacial superimposition by using complex mathematical principles, high-level programming skills, and high-performance tools requiring operators in the field of craniofacial superimposition with a high level of mathematical knowledge and programme usage.

In Thailand, no research or operation of craniofacial superimposition has utilised computer programmes with mathematical principles. Most of the operators in Thailand do not have expertise in applied mathematics programming. Therefore, the original craniofacial superimposition by using image overlapping has not been developed for making decisions.

The researchers desired to develop craniofacial superimposition in Thailand to be more efficient and reliable, applying relevant mathematical programmes and mathematical principles to show the numerical resemblance assessment values which will be especially useful. This research maybe able to facilitate, be faster, more reliable, easy to use and save budget in identifying process. Individuals as well as being a starting point for development of forensic science by using technology in various fields to further expand in the future.

MATERIALS AND METHODS

In this research, the experiment was about applying mathematical programme for craniofacial superimposition with selected sample of skulls and face images obtained from the Forensic Osteology Research Center (FORC) of the Faculty of Medicine, Chiang Mai University, Thailand. They were divided into 10 males and 10 females. The age at deaths of individuals in the sample ranged from 20-60 years. Skulls were not broken and had a mandible bone.

After determined sample in the experiment, the operation can be divided into 2 parts: i) The process of skull photography and quality adjustment image of the sample. ii) The process of designing and writing operation within mathematical programme, then testing the operation of developed programme.

First part of the research was to collect data of samples, in which the skull images were taken for the experiment. Before taking the photograph, the cranium and mandible parts of the skull were assembled together by a glue tape. That worked as temporomandibular ligament to connected cranium and mandible (Fehrenbach & Herring 2002). In case of decayed alveolar process due to lost of teeth (Mahakkanaukrauh 2013), we used a clay replacement in that part. After assembling the parts, face angle was arranged to look like the face photo of the sample. When completely reassembled the skull, then we took a photo and forwarded into process of resizing and improving quality of the photo, by adjusting brightness, contrast and sharpness of picture for clearly edges.

The second part was design and write operation within mathematical programmes. This research applied

Table 1: Male craniofacial superimposition resemblance assessment

Case	Face-Real skull	Face-Randomized skull	Difference
M1	14,782	10,667	4,115
M2	11,707	6,756	4,951
M3	10,393	8,457	1,936
M4	14,116	9,467	4,649
M5	11,386	8,658	2,728
M6	14,172	11,805	2,367
M7	8,752	6,534	2,218
M8	6,453	6,264	189
M9	14,390	12,594	1,796
M10	15,106	8,409	6,997

mathematic programme in craniofacial superimposition for resemblance assessment of facial photo and skull photo, by using the relation of edge from the photo which displayed in binary form value (0 and 1) for comparison. This method can be correlated as overlapping images in craniofacial superimposition.

RESULTS

Experiment in research study, took 20 sample cases, consisting of 10 males and 10 females. All the samples needed improved image quality and size, were to be consistent and suitable for the experiment. The processing accorded to the objectives of the research, was presented in the form of a test report table.

The tables showed the summaries of the overlapping points, after images were analysed. They were divided into a table analysis of male and female gender results by the difference of acceptable yield overlapping points from face-real skull and face-randomised skull more than 1,000 points.

Table 2: Female craniofacial superimposition resemblance assessment

Case	Face-Real skull	Face-Randomized skull	Difference
F1	11,004	10,113	891
F2	9,116	10,145	1,029
F3	14,670	12,993	1,677
F4	9,516	8,922	594
F5	7,434	6,269	1,165
F6	8,950	6,097	2,493
F7	15,785	15,064	721
F8	6,908	5,662	1,246
F9	5,493	4,215	1,278
F10	4,389	2,455	1,934

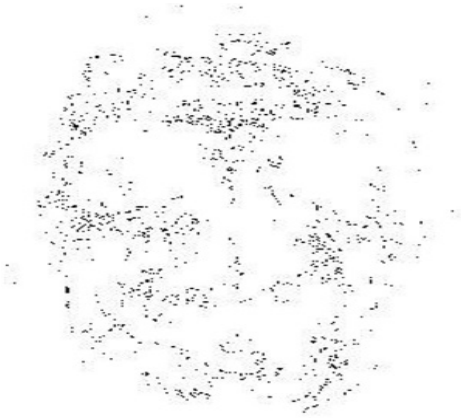

Figure 1a: Overlapping points after analyzed in face-real skull.

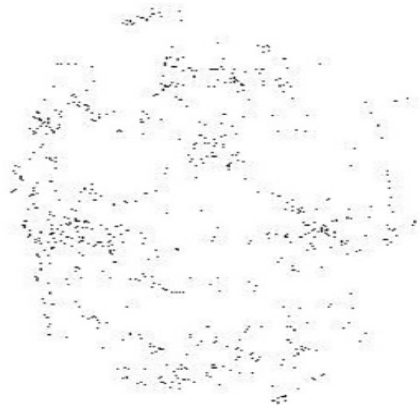

Figure 1b: Overlapping points after analyzed in face-randomized skull.

Table 1 showed 10 males and 9 cases had different overlapping points in acceptable yield between Face-Real skulls and Face-Randomised skulls. Case M10, had the most points of difference in the group of males.

Table 2 showed 10 females with 6 cases revealing different overlapping points in acceptable yield between Face-Real skull and Face-Randomised skulls. Case F6 had the most points of difference for the females.

From the experiment in both males and females, males could be analysed more accurately. Males had less of a subcutaneous fat layer on the face than females, which made the detection of important edges of the facial bone structure.

In the case of M10, the difference of the overlapping points between the experiment of Face-Real skull and Face-Randomised skull was clearly seen. The image showed the overlapping points of the Face-Real skull (Figure 1a) with the density on face area and there was a continuation of edges in craniofacial superimposition key points which was more than Face-Randomised skull (Figure 1b).

DISCUSSION

The experimental research applied Mathematics programming in craniofacial superimposition for resemblance assessment of facial photos and skull photos, in 20 cases of the sample. The programme calculated the overlay position of skull and face photo from the same owner then compared it to the calculation the overlay position of the face and randomised skull photo. The difference of acceptable yield was 15 cases of 20 cases. There were more than 1,000 different overlapping points of face-real skulls and face-randomise skulls. This was 75% success of the experiment.

Regarding M10, the face-real skull experiment described 15,106 overlapping points. The face-randomised skull found 8,409 overlapping points. The face-real skull found 6,997 more overlapping points than the face-randomised

skulls. The differences showed a clear result. In this case, M10 had some subcutaneous fat layers on face which required adjustment to sharpen the image for a clear edge. This process created a lot of variances in image. The real skull and randomised skulls had intensive color, causing many variances in the skull image as well. Therefore, when overlapping had a lot of matched points. However, this case could analyse correctly and clearly distinguish.

In the experiment of F2, the face-real skull experiment was 9,116 overlapping points. A face-randomised skull found 10,145 overlapping points. The face-real skull found 1,029 overlapping points less than face-randomised skulls. The differences showed a result that incorrectly analysed. In case F2 had much subcutaneous fat layers on the face, loose skin, and wrinkles. This requires adjustment that sharpens the image for a clear edge, so this process creates a lot of variances in image. In addition, the surface of photo has pattern that causes variations edge analysis. Therefore, when overlapping these problems made an incorrect analysis because they matched in unwanted areas.

The selection of samples in this research for the experiment is very important because various factors can affect the image analysis. In some cases the quality of the photo is a problem, as old, non-sharpness, grayscale or damaged image. Some samples that have a greater subcutaneous fat layer limiting the ability to clearly see the bone structure in the face. These samples made discrepancies in the results by creating noise in the image because of the need to sharpen adjustment for clear edges of the face. In the edge analysing process, it showed results in 1 binary value. These analysed edge on the face included areas that we do not need. In the part of uneven surface color on skull, result of analysed edge is 1 in a binary value. This means that the analysed edge of skull included unwanted area. While comparing the important points, matching occurred in the same position with the same values, which occurred in that area and were not just the edge of face, resulting in discrepancies.

This research was an alternative craniofacial superimposition with a different method. The method used image edge theory that aimed to compare important points in craniofacial superimposition, such as the area that bone which was seen under the skin of the face structure. This research, which was still a prototype programme that used simple mathematical theories and had some deviations, could be analysed and applied by using the number of overlapping points as indicators and still required working with a mathematical programme that does not have a graphic user interface to support the operator. When compared to the reference research, they used sophisticated mathematical theories to detect important points on the face for analysis (Campomanes-Alvarez et al. 2014; Campomanes-Alvarez et al. 2018; Gaudio et al. 2016). There was a higher cost of operation and could be done in a semi-automatic system to detect important points

(Campomanes-Alvarez et al. 2014; Campomanes-Alvarez et al. 2018). There are still deviations in the analysis results (Campomanes-Alvarez et al. 2014; Campomanes-Alvarez et al. 2018; Gaudio et al. 2016), that need to be developed in the future.

Programmes developed in the future must have more efficacy by using advanced mathematical principles to reduce the error of results, work as a ready-to-use programme with the ability to analyse similarities successfully at 90%.

CONCLUSION

This research applied mathematics programming in craniofacial superimposition to resemble assessment of facial and skull photos. The mathematical analysis ability of this programme also has basic mathematical and basic functions. It can be considered as a prototype programme that needs further development. The selection of samples for test in the programme should have clearer inclusion criteria and exclusion criteria to reduce analysis variances.

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