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Forensic Anthropology Population Data

Comparison on three classification techniques for sex estimation from the bone length of Asian children below 19 years old: An analysis using different group of ages

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ABSTRACT

Sex estimation is used in forensic anthropology to assist the identification of individual remains. However, the estimation techniques tend to be unique and applicable only to a certain population. This paper analyzed sex estimation on living individual child below 19 years old using the length of 19 bones of left hand applied for three classification techniques, which were Discriminant Function Analysis (DFA), Support Vector Machine (SVM) and Artificial Neural Network (ANN) multilayer perceptron. These techniques were carried out on X-ray images of the left hand taken from an Asian population data set. All the 19 bones of the left hand were measured using Free Image software, and all the techniques were performed using MATLAB. The group of age "16–19" years old and "7–9" years old were the groups that could be used for sex estimation with as their average of accuracy percentage was above 80%. ANN model was the best classification technique with the highest average of accuracy percentage in the two groups of age compared to other classification techniques. The results show that each classification technique has the best accuracy percentage on each different group of age.

1. Introduction

Precise sex identification of human skeleton is an important factor in both forensic practice and bio-archaeological contexts. Various body features have been analyzed in the estimation of sex including femur [1,2], patella [3], mandibular [4,5], calcaneus [6], occipital condyle [7], and hand bone [8,9]. For the latter, DFA is the most commonly used technique for sex estimation when determining data [1–9], while non-linear classification techniques such as SVM and ANN [1,3] are seldom used.

It is a very complex task to diagnose the sex of a human skeleton from morphological features [10]. It also depends on the completeness and expression of sexual dimorphism in the recovered structures. The task becomes extremely challenging when dismembered and mutilated human remains are the only materials to be used by forensic pathologists for examination. There are several inherent limitations affected by different criteria, such as ethnicity, socio-economic citation, nutritional and geographical location in the estimation of sex. It has been concluded that results obtained from a certain population may be not applicable in others. As such, specific studies have to be performed as the results would be unique to a particular population [11]. All the reported techniques of determining sex are also unique for that particular study and may not be applicable for available different samples or datasets.

When it comes to determining the sex of an individual based on the measurements of hand bone, there is limited published evidence of the real advantage in using non-linear techniques such as SVM and ANN over discriminant analysis. Indeed, discriminant analysis is an economic, robust and easy-to-use modeling technique compared to other techniques, which are quite complicated and time consuming to implement [1]. The SVM and ANN can represent a real alternative to classical statistical modeling techniques for data sets showing non-linearities, data fitting and prediction abilities [12]. With the limited use of these non-linear classification techniques of bone measurement, this study estimated and compared the accuracy percentage of three classification techniques to determine the best classification technique and group of age for sex estimation.

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2. Materials and methods

A total of 333 X-ray images of Asian population left hand bones with 166 males and 167 females were included in this study. To overcome ethical issues, these radiographs were collected from the Children Hospital Los Angeles, along with patients' demographic data and radiologists' readings distributed in 19 groups (newborn, 1–18), both male and female. The radiographs were collected by the Image Processing and Informatics Lab of the University of Southern California and funded by the National Institute of Health, and allowed for open research and education purpose only. Candidates for this study underwent a protocol approved by an institutional review board for clinical investigations. Each radiograph was digitized to a 2 K $\times$ 2 K image using a laser film scanner (Array, Tokyo, Japan), and the patient demographic records were manually entered via the scanner GUI (graphical user interface) and saved as a DICOM file [13]. The radiographs can be taken at this website [14]. The age and gender of all radiographs were perfectly documented as a reference. This study has also been approved by the Ministry of Higher Education, Malaysia and the ethics committee of our Research Management Centre, Universiti Teknologi Malaysia.

The bones on the left hand can be divided into four groups, namely distal phalanx, middle phalanx, proximal phalanx and metacarpal. The middle phalanx group consists of four bones while the other three groups have five bones each, with the total number of bones for the hand being 19 (Fig. 1). The data set ranged from newborns to 19 years old with no records of bone problems or bone

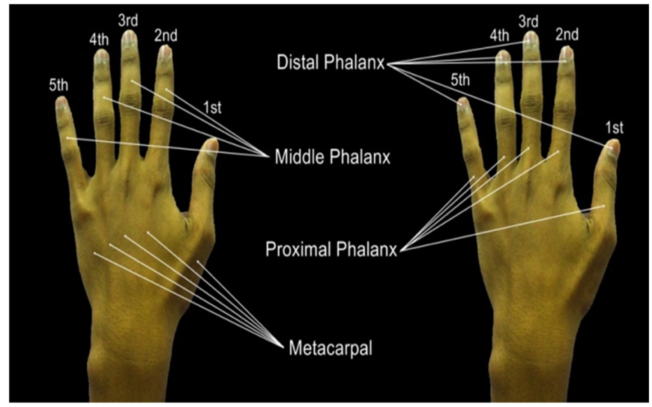

Fig. 1. Left Hand Bone with labels.

diseases such as fractures, bone cancers, osteoarthritis, rheumatoid arthritis or other genetic bone problems. Bones with these complications should not be included as they are expected to be weakened, brittle, deformed and easy to break, which may affect the measurements.

To measure the bone length, a free photo editor (Photo Pos Pro, Power of Software Company Ltd.) was used. This software was used to measure all 19 bones by creating a line in each bone starting from the base-middle point of bone to the end-middle point of bone on each X-ray image, and the length of the line in centimeter

Table 1
Intra-observer trials. Variance analysis for repeated measures (three measures for each bone in every image) (p-value > 0.05).

			df	Type III sum of squares	Mean square	F	p-Value
Distal phalanx	1st	Measures	2	0.765	0.383	1.396	0.248
		Error (measures)	660	180.780	0.274		
	2nd	Measures	2	0.845	0.423	1.658	0.191
		Error (measures)	660	168.233	0.255		
	3rd	Measures	2	0.823	0.412	1.871	0.155
		Error (measures)	660	145.123	0.220		
	4th	Measures	2	0.800	0.400	1.513	0.221
		Error (measures)	660	174.500	0.264		
	5th	Measures	2	0.787	0.394	1.991	0.137
		Error (measures)	660	130.465	0.198		
Middle phalanx	2nd	Measures	2	0.960	0.480	1.663	0.190
		Error (measures)	660	190.463	0.289		
	3rd	Measures	2	0.831	0.416	1.767	0.172
		Error (measures)	660	155.230	0.235		
	4th	Measures	2	0.877	0.439	2.409	0.091
		Error (measures)	660	120.120	0.182		
	5th	Measures	2	0.745	0.373	1.642	0.194
		Error (measures)	660	149.698	0.227		
Proximal phalanx	1st	Measures	2	0.689	0.345	1.474	0.230
		Error (measures)	660	154.250	0.234		
	2nd	Measures	2	0.745	0.373	1.325	0.267
		Error (measures)	660	185.520	0.281		
	3rd	Measures	2	0.665	0.333	1.170	0.311
		Error (measures)	660	187.633	0.284		
	4th	Measures	2	0.801	0.401	1.807	0.165
		Error (measures)	660	146.321	0.222		
	5th	Measures	2	0.713	0.357	1.407	0.246
		Error (measures)	660	167.254	0.253		
Metacarpal	1st	Measures	2	0.511	0.256	0.916	0.401
		Error (measures)	660	184.021	0.279		
	2nd	Measures	2	0.431	0.216	1.084	0.339
		Error (measures)	660	131.200	0.199		
	3rd	Measures	2	0.489	0.245	0.975	0.378
		Error (measures)	660	165.487	0.251		
	4th	Measures	2	0.846	0.423	1.529	0.218
		Error (measures)	660	182.632	0.277		
	5th	Measures	2	0.746	0.373	1.294	0.275
		Error (measures)	660	190.230	0.288		