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Research Report

Automation of gender determination in human canines using artificial intelligence

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ABSTRACT

Background: *Gender determination is an important aspect of the identification process. The tooth represents a part of the human body that indicates the nature of sexual dimorphism. Artificial intelligence enables computers to perform to the same standard the same tasks as those carried out by humans. Several methods of classification exist within an artificial intelligence approach to identifying sexual dimorphism in canines.* ***Purpose:*** *This study aimed to quantify the respective accuracy of the Naive Bayes, decision tree, and multi-layer perceptron (MLP) methods in identifying sexual dimorphism in canines.* ***Methods:*** *A sample of results derived from 100 measurements of the diameter of mesiodistal, buccolingual, and diagonal upper and lower canine jaw models of both genders were entered into an application computer program that implements the algorithm (MLP). The analytical process was conducted by the program to obtain a classification model with testing being subsequently carried out in order to obtain 50 new measurement results, 25 each for males and females. A comparative analysis was conducted on the program-generated information.* ***Results:*** *The accuracy rate of the Naive Bayes method was 82%, while that of the decision tree and MLP amounted to 84%. The MLP method had an absolute error value lower than that of its decision tree counterpart.* ***Conclusion:*** *The use of artificial intelligence methods produced a highly accurate identification process relating to the gender determination of canine teeth. The most appropriate method was the MLP with an accuracy rate of 84%.*

Keywords: *sexual dimorphism; canines;artificial intelligence; automation*

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INTRODUCTION

Determining the gender of an individual constitutes an important element within the human identification process which can be accomplished by measuring the skeleton. This measurement is obtained through a comparison of males and females.[1] Teeth, being one part of the human skeleton, can be measured in both living and deceased humans.[2] The measuring of teeth, a method known as odontometry and considered easily applicable, inexpensive, and reliable, provides useful information for the purposes of determining gender within a defined population.[3]

Teeth constitute the most durable part of human body, able to withstand various external irritants; biological, chemical, mechanical, or temperature-related. Tooth morphology executes an important role, not only in indicating differences between the activities associated with occlusion and determining the frequency of dental tissue and skeletal anomalies in orthodontic treatment, but also in sex determination.[4] The gender difference is evident from the permanent dentition due to hormonal variations specifically affecting the respective size and shape of the two genders prior to adulthood.[5]

Among human teeth, canines demonstrate the highest degree of sexual dimorphism, as demonstrated by studies conducted on multiple populations. Canines are retained longer compared to other teeth due to their rarely suffering from caries and periodontal tissue damage. The ability of primates to survive is also shown in the course of the gender identification process by means of odontometric analysis to

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be dependent upon canine teeth due to their high durability and utility.[6]

In humans, canine size has been shown to constitute a significant difference between males and females, but the process of manual measurement is of greater duration and requires an expert operator to arrive at a determination of gender. The use of a computer-based gender classification model can significantly accelerate this process since it consists of a mathematical formula implemented by an algorithm that allocates data to certain categories or classes.[7] The classification model emerged from data pattern extracts by using the algorithm of an artificial neural network (ANN) which constitutes a method of artificial intelligent (AI).[8] There are several classification methods potentially employable in this case. However, the most appropriate process for the identification of sexual dimorphism based on canine size should be determined by means of several factors, including; accuracy, error rate, and level of agreement between experts as to the particular classification model to be applied.[9]

The central focus of AI is the feasibility of developing an intelligence system approximating human ability with the intention of combining software and hardware. Within this system, one particular area of observation is referred to as an expert system which stores the ability of an expert in a particular domain within a computer program enabling the machine to make decisions or find solutions. These systems are applied in various fields such as medical diagnostics, exchange markets, robotics, law, science, and entertainment.[10] The implementation of this system is expected to accelerate the identification of gender and respond to present day challenges requiring scientific analysis of large amounts of data.[11]

MATERIAL AND METHODS

The research subjects consisted of 150 student dental cast models, equally divided between male and female, from the dental laboratory collections of Universitas Brawijaya and Universitas Airlangga. The model employed was caries-free, with no abnormalities in the canine maxilla or mandibula. Measurement of the mesiodistal, buccolingual, and diagonal (mesiobuccal distolingual and distobuccal mesiolingual) diameter of maxillary and mandibular canines for all models was effected by means of a Tricle Brand vernier caliper no.3965-006 Prohex Technology Germany using a millimeter (mm) scale. The method of measuring the canine diameter is shown in Figure 1.

The diameters of the mesiodistal, buccolingual and diagonal of maxillary and mandibular canines of both genders were inputted into an application computer program implementing the algorithm multi-layer perceptron (MLP). One hundred cast models that equally divided in number between male and female were then used as training data calculated by means of the algorithm Naive Bayes, decision tree, and MLP in a 3.91 Weka program on a computer with an Intel Core i3 processor. Analysis was conducted by the program in order to obtain data patterns. Further testing was carried out using 50 new measurement results from 25 members of either gender. Measurement data from another 50 cast models that divided equally between male and female was subjected to testing in order to measure the accuracy of gender identification using AI methods.

The statistical analysis applied consisted of Cohen's Kappa coefficient with a value range of 0-1. The value match between the training data and testing data was calculated using Cohen's Kappa coefficient which is a method of measuring the validity and reliability of the data.

RESULTS

The data relating to mesiodistal, buccolingual, and diagonal (mesiobuccal distolingual and distobuccal mesiolingual) maxillary and mandibular canines was entered into the Weka program 3.9.1. Three methods of artificial intelligence were employed that demonstrate the extent of matched value between experts and the results of the system.

The implementation results for the three models of classification; Naive Bayes, decision tree, and MLP are contained in Tables 1, 2 and 3. Table 1 features simulation method results relating to a research population of 50 canines. Application of the Naive Bayes method classified the correct data as 0.82, the error rate as 0.18, the level of agreement with the expert as 0.64 and the mean absolute error as 0.2288. The mean absolute error is a value that indicates the average absolute error between the system

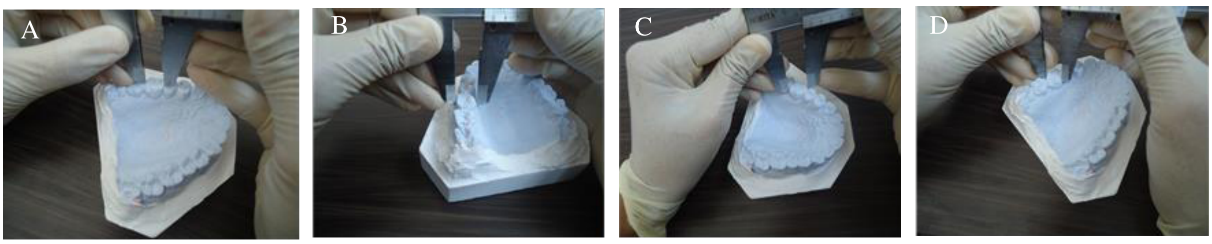

Figure 1. Measuring the canine diameter; A) mesiodistal; B) buccolingual; C) mesiobuccal distolingual; D) distobuccal mesiolingual.

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outcomes and the actual results.[12]

Table 2 describes the implementation results of the decision tree method. The correct data was 0.84, the error rate 0.16, the level of agreement with the expert 0.68 and the mean absolute error 0.2528. Table 3 contains the results of the MLP method. The correct data was 0.84, the error rate 0.16, the level of agreement with the expert 0.68 and the mean absolute error 0.2049.

The three methods of classification demonstrate almost the same performance if implemented on a case identification of canine sexual dimorphism. Based on the comparison of results graph in Figure 2, the Naive Bayes method provides lower classification accuracy than either of the other two methods. The correct data was 0.82, the error rate 0.18, the level of agreement with the expert 0.64 and the mean absolute error 0.2049. The decision tree and MLP methods have the same level of accuracy with regard to true/false classification and its Kappa value. Concerning accuracy, the decision tree and MLP methods constitute appropriate choices. However, one more indicator should be considered in the classification process, namely; the mean absolute error. MLP has a mean absolute error lower than that of decision tree. This value indicates that the average error occurring during the classification process recorded by MLP was lower than that of decision tree. Therefore, as far as canine sexual dimorphism is concerned, the most appropriate method delivering optimum performance was that of MLP.

Table 1. Results of Naive Bayes method

No.	Indicator	Value
1.	Correctly classified instances	0.82
2.	Incorrectly classified instances	0.18
3.	Kappa statistic	0.64
4.	Mean absolute error	0.228

Table 2. Results of decision tree method

No.	Indicator	Value
1.	Correctly classified instances	0.84
2.	Incorrectly classified instances	0.16
3.	Kappa statistic	0.68
4.	Mean absolute error	0.2528

Table 3. Results of MLP method

No.	Indicator	Value
1.	Correctly classified instances	0.84
2.	Incorrectly classified instances	0.16
3.	Kappa statistic	0.68
4.	Mean absolute error	0.2049

DISCUSSION

The term 'sexual difference' refers to the contrasts in the size, height, and appearance of males and females.[4] The analysis of teeth provides reliable information with a low incidence of observer error. However, it also needs to provide a high level of measurement accuracy due to the relatively small dimensions involved.[13]

Tooth-based sexual determination relates to the size and shape of the teeth since male teeth are usually larger than those of females.[14] Certain ancient non-human primates and extinct hominid species exhibit dental dimensions of sexual dimorphism, especially in the case of canine teeth. This dimorphism is most probably the result of intra-species evolutionary selection and rivalry of a sexual, territorial or other resource-based nature.[15] Certain studies show significantly different results with regard to the diameter of both maxillary and mandibular canines in each of the two genders.[16,17]

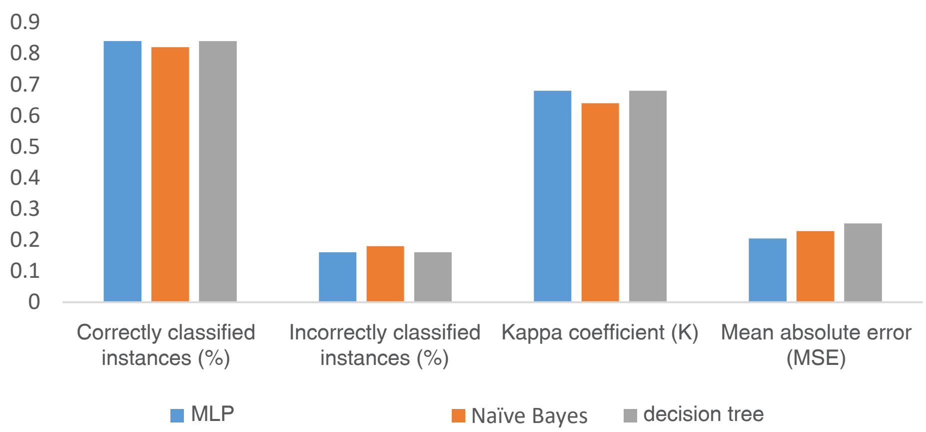

Figure 2. Comparison of Correctly Classified, Incorrectly Classified, Kappa Coefficient and MAE of classification methods.

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Among the range of human teeth, the canines can be regarded as key to understanding the jaw due to their size, sturdiness, and morphological resistance to caries and periodontal disease because they survive relatively longer than other teeth. Their length and sturdy shape also enable them to withstand severe post-mortem conditions such as explosions or air disasters.[18]

Different mean values between males and females are found in all dimensions of canine teeth, mesiobuccal and distolingual. Statistical results of the study indicate significant differences between male and female.[19] The results presented here are in accordance with those of other odontometric studies found not only in humans, but also in anthropoid apes and certain species of monkey. The canines of the two jaws of the species are more dimorphic than those of others, while the upper teeth of males all possess a much larger buccolingual dimension. Another study also confirmed that male tooth size is larger than that of females and canine teeth represent the largest sexually dimorphic teeth.[20,21]

The gender-determined dimorphism of teeth has been analyzed from a genetic perspective within which it is reported that the Y chromosome can affect tooth growth by increasing mitotic activity through amelogenesis and dentinogenesis, resulting in dentine thickening in males. The amelogenin gene, found in both X and Y chromosomes, implies dimorphism with regard to tooth size. No significant differences between the sexes with regard to thickness of the enamel were detected, while the deposition of dentine was more prominent in males than females. These findings were in keeping with data from the results of the research conducted. Mitosis occurred in the Y chromosomes, permitting the deposition of enamel and dentin, while in the X chromosomes deposition was limited to enamel alone. This may explain the difference in size between male and female teeth (especially linear measurements) noted in the literature.[14] In contrast, sex hormone modification is of more limited interest.[5]

A statistically significant difference was also evident in relation to tooth volume. However, due to the effects of aging on the pulp chamber, its volume-related results and ratio to less gender-related dental volume dimorphism are more appropriately studied by age rather than sex.[14]

Gender determination by means of artificial intelligent was performed in several stages. Firstly, tooth size data was collected and labelled "canines". Secondly, an MLP learning process was conducted. Thirdly, an MLP testing process and the analysis of results were completed. The labeled data was that which had already been categorized as male or female. Data relating to canine tooth size was obtained from measurements of dental cast impressions. The next step consisted of the learning process using MLP models, the objective of which was to explore the pattern of existing data on the size of the dataset of labelled canines. The central focus of this learning process was the search for weight value (w) that was appropriate to the classification model. The weighing process was repeated until the optimal weight values for the classification process had been identified.

The testing process or trial constituted a procedure to assess the classification model against a set of labelled data. The classification model developed during the learning process would be used to identify gender. The data used in this testing process consisted of labeled data, whose results would be compared with the data system of testing so that the performance of the Naive Bayes, decision tree, and MLP model could be examined. Analysis of the results was affected by comparing the system results and those of the data testing. The process of extracting data was completed by running a learning process on the classification model using labeled canine size data. After obtaining the pattern and applying a classification model, the determination of gender on the basis of canine size could be completed. Test results based on a statistical approach were used to arrive at a conclusion. The characteristic of every method was that point at which the model was most relevant to this case. In conclusion, the use of AI methods produced a highly accurate identification process relating to the gender determination of canine teeth. The most appropriate method was the MLP with an accuracy rate of 84%.

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