

Bite Mark Identification Using Neural Networks: A Preliminary Study

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Abstract—Forensic dentistry generally addresses the problem of identifying individuals based on the some specific characteristics of teeth or bite mark impressions. Bite mark identification process generally involves human interaction and has human bias. It would be beneficial to have a system that reduces human bias and has high accuracy matching performance. This paper describes a preliminary study to verify the effectiveness of applying the neural network approach in bite mark identification. By selecting some specific features of the bite marks for the model, trained networks give reasonable result for the matching accuracy in this initial study.

Index Terms—Bite mark identification, forensic dentistry, image analysis, neural network application

I. INTRODUCTION

Bite mark is a type of evidence which may be found after a crime. However, this type of evidence is controversial and needs further study. Many methods for bite mark identification have been proposed ranging from manual approach, semi-automatic approach, toward fully automatic approach in recent years [2-5]. Several algorithms for comparison process have been applied to improve the accuracy of the identification. The Artificial Neural Network (ANN) is an adaptive system which changes its structures based on external and internal information that flows through the network during the learning phase, and is suitable for analyzing complicated relationship [1]. A review of the literature identified three studies in which ANN were applied to caries detection in teeth and human craniofacial growth analysis and classification [6-8].

This preliminary study was aimed to verify the success of applying ANN in bite mark analysis by testing 34 specific features of bite marks which were registered on pink wax to have a clear view of the bite mark.

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II. MATERIALS AND METHODS

Data Collection

Bite mark samples were acquired from 50 Thais with an age range of 18-25 years. The assumptions in this study for each sample are no missing any of lower and upper anterior teeth and no fixed orthodontic appliances. Each sample was asked to bite on standard pink dental wax with five different biting positions which chosen from the following list; 1) faced front standing, 2) face front sitting, 3) chin down standing, 4) chin down sitting, 5) chin up standing, 6) chin up sitting, 7) supine position, 8) prone position, 9) left bed side position, 10) right bed side position. Bite marks of all upper and lower anterior teeth were covered. Next, Photographs of these bite marks were captured with a digital camera Panasonic LX3 (Panasonic Corporation, Osaka, Japan). The resolution is 11.3 million pixels and the distance between the objects and lens was 25cm. These photos were stored as JPEG files as bite mark samples. Thus, there were a total of 250 bite mark samples and only bite marks from lower teeth were used for ANN training in this study.

Pre-processing techniques

Each bite mark sample was transformed from bit depth of 32 to 8-bit gray scale (0-255), where 0 is the darkest and 255 is the brightest. Later, each image was adjusted its contrast by using Contrast Limited Adaptive Histogram Equalization. Region of interest covering only all anterior teeth was cropped. Then the median filter was applied to enhance the border of each tooth bite mark, followed by converting the image to black and white format, as illustrated in Fig.1-3.

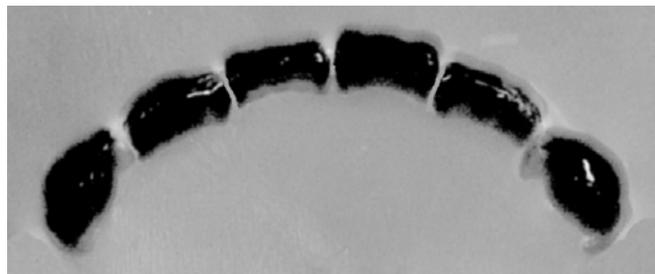


Fig.1. Initial bite mark image

Feature Selection

Accuracy level of the identification process depends heavily on the appropriateness of the selected features. In this preliminary study, some criterions need to be

considered in the process of selecting suitable features. The selected feature should be invariant to the angle of the image and the pressure of the biting on the wax.



Fig.2. Sample bite mark image after edge detection



Fig.3. Sample bite mark image in black and white format.

Although some features have good potential, extracting process of such features might be prohibitively complicated.

Seven initial groups of features were selected as input data for ANN modeling in this study:-

1) **CC** : Distance from the centric point of the left canine to the right canine (CC line). Each sample then gave only one data from this feature type, as shown as the bottom line in Fig.4.

2) **I-LC Angle**: Angles between a straight line from centric point of each anterior tooth to centric point of the left canine and the CC line. Each sample then gave four data from this feature type, as shown in Fig.4.

3) **I-RC Angle**: Angles between a straight line from centric point of each anterior tooth to centric point of the right canine and the CC line. Each sample then gave 4 data from this feature type, as shown in Fig.4.

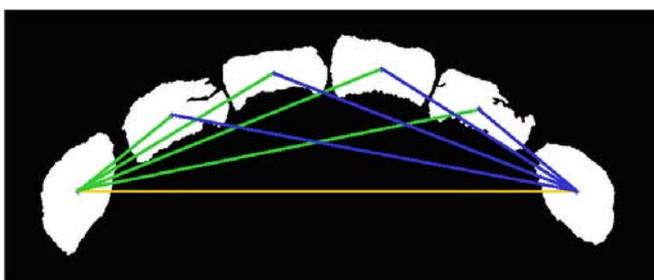


Fig.4. Feature type#1, #2, #3

4) Angles between horizontal line and these following lines:

1. line from 2nd centric point to 3rd centric point
2. line from 2nd centric point to 4th centric point
3. line from 2nd centric point to 5th centric point

4. line from 3rd centric point to 4th centric point
5. line from 3rd centric point to 5th centric point
6. line from 4th centric point to 5th centric point

Each sample then gave 6 data from this feature type, as shown in Fig.5.

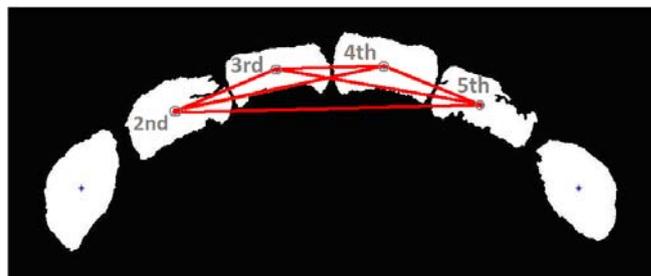


Fig.5. Feature type#4

5) **Coefficient A** : The curvature of the parabola shape which is best fit the set of centric points of the anterior teeth. The curvature is obtained from the equation:

$$Y = Ax^2 + Bx + C \quad (1)$$

Each sample then gave one data from this feature type.

6) **iRatio**: Ratio of distances which is the shortest I-CC/I-CC of each incisor teeth. Each sample then gave four data from this feature type (Fig.6).

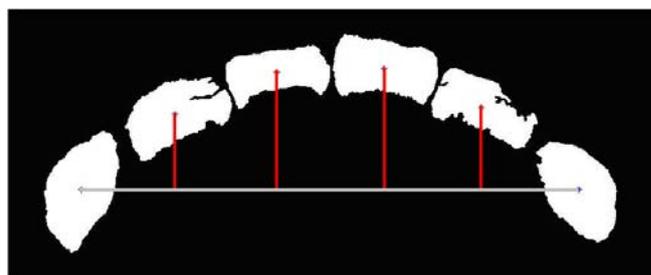


Fig.6. Feature type#6

7) **HTT-D**: Distance between two tooth centric points projected on the CC line. Distance from the centric point of the left canine to the right canine, which was the feature type#1 (CC), was not included in this feature type. Each sample then gave 14 data from this feature type, as shown in Fig.7.

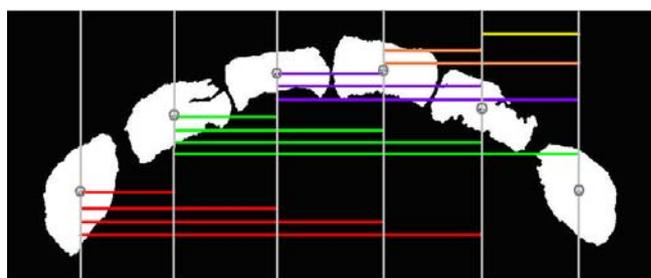


Fig.7. Feature type#7

Network Selections, Training, Testing

Multi-layer feed-forward neural network model was used with 34 inputs, which were equal to the number of selected features, and one hidden layer with 40 hidden neurons. Tan-sigmoid function was used as the transfer function of the hidden nodes and the output nodes. Bias and weight values were adjusted to minimize the mean squared error in (2).

$$F = mse = \frac{1}{N} \sum_{i=1}^N (e_i)^2 = \frac{1}{N} \sum_{i=1}^N (t_i - a_i)^2 \quad (2)$$

Gradient descent algorithm was used for adjusting the weights and biases in the training process with the help of Levenberg-Marquardt algorithm to provide the numerical solutions. Then ANN network was trained for the optimum sensitivity and specificity. Later, a sample group of the 50 Thais then repeat biting on pink wax once with only one biting position. All these bite marks then were run through the process of features extraction. After that all data will be given into the trained networks as inputs, to test for the validity of the network's sensitivity.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The identification performance of this network in correct matching between the bite marks and the bite mark owners from 100 runs of testing with randomly selected test set is in the range of 78-86 % with the average accuracy approximately 82%.

Even the result from this preliminary study of the performance of the neural network for the bite mark identification is not high level of accuracy, it shows that this approach has potential and needs further study to improve the performance.

Fig. 8-9 illustrate two sample cases of incorrect identification. The images on the top are the test case and the images on the bottom are the bite mark images of the incorrectly identified owners. Some feature values the pair are very similar. These results show that the selected features with the model in this study are not able to differentiate these different bite marks correctly. One of the reasons is that all the angles measured in this study use the tooth centric point that may not represent person's identity well. Angle of the planar axis of each tooth with some reference line might be a better feature. Further study needs to be done to consider which feature has higher level of influence to the accuracy than other features.

New features might be needed to improve the performance, such as the planar angles of each tooth that might need image processing techniques to obtain automatically, or some other coefficients of higher order polynomial. Furthermore, more powerful algorithms for identification process are needed.

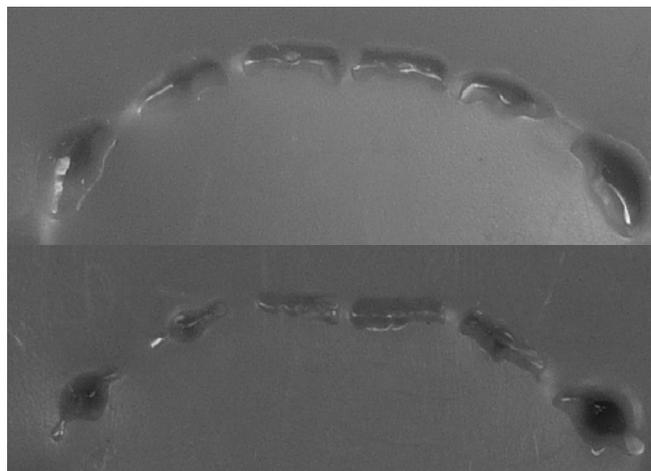


Fig. 8. Sample incorrect identification result#1 : bite mark in the top image in the test set was wrongly identified by the trained network to be closest to bite mark in the bottom image.

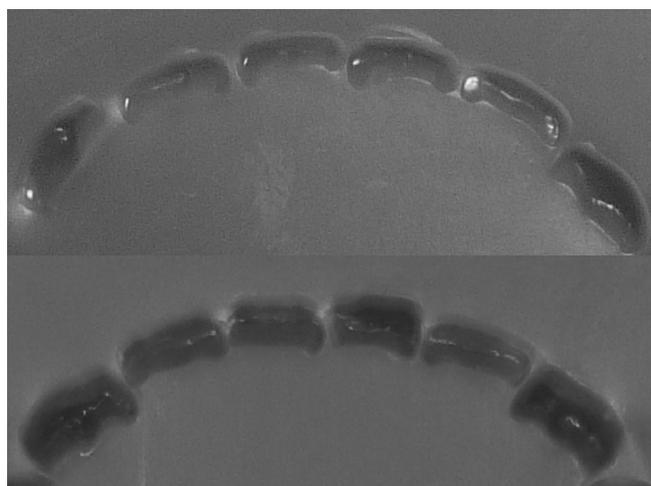


Fig. 9. Sample incorrect identification result#2 : bite mark in the top image in the test set was wrongly identified by the trained network to be closest to bite mark in the bottom image.

Directions for future works are the study on feature selection to improve the accuracy and different approaches and methods on the algorithms for identification. In this preliminary study, there are some limitations and constrains on the bite mark images. The images obtained from impression on the wax yield very high quality bite mark images for the input that considerably ease the feature extraction and identification processes. This assumption is not quite close to the real life situation. To make the results move closer to the real world, the bite mark images might need to obtain from the impression on some materials that are very similar to the human skin. In addition, this study focuses only on the cases that no missing any of lower and upper anterior teeth and no fixed orthodontic appliances. The cases that have missing teeth or the cases that have the incomplete bite mark images are also needed to be considered.

IV. CONCLUSION

Currently, forensic odontology became more popular and bite marks are types of evidence which may involve with crimes. They sometimes were used to identify criminals. This preliminary study was aimed to verify the possibility of applying ANN in bite mark identification by using 34

specific features of bite marks which were registered on pink wax. The experimental results show reasonable level of accuracy. However, further studies are needed in the feature selections process and the approaches and methods for the classification to improve the bite mark identification accuracy and to be able to work with incomplete bite mark images. While the higher level of accuracy is obtained, computer-aided analysis is only aimed to eliminate the human bias as much as possible and the manual analysis is still required. The application of this study may not be used to identify the crime at this stage. However, in the case of mass disaster, such as air crash, if the bite marks can be obtained prior to the travel, this information might be useful to identify the passengers.

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