Machine Learning Based Gender Detection Using Craniometric Analysis

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Abstract:
In the field of forensic anthropology, anthropologists develop a biological profile as a contribution to the identification of unknown individuals. In developing this biological profile, determination of gender is the foremost step. Often anthropologists come across this task of gender identification of decomposed skeletons, especially during the course of criminal investigation. Here, the human skull is of great help since it displays a degree of sexual dimorphism in case of sex determination of unidentified individuals. Hence, we are using craniometry along with image processing and machine learning for near accurate results. If a machine can learn the process of gender detection, it will be advantageous in the forensic world considering its performance. In order to teach this process to a machine, approximately 29 cranial metrics calculated on the basis of a few vital points on the human skull are taken into consideration, and we have used image processing to determine these metrics from skull images. Here, we make use of two machine learning techniques namely Neural Networks (NN) and Support Vector Machine (SVM) to play with the data set of cranial metrics. As a result, both the techniques yielded more than 80% accuracy in discriminating male and female skull.

Keywords: Cranial Metrics, Gender Detection, Image Processing, Neural Networks, Support Vector Machine.

I. INTRODUCTION
The list of extensive research areas includes gender detection due to its powerful applications in anthropology, forensic world and other areas\textsuperscript{[1]}. Most of the work in this area has been focused on visual observation and slight prediction by practitioners till date. Over past decades, gender detection based on facial images, fingerprints, frontal bone of human skull are performed by researchers. At times this determination can prove to be really challenging and at the same time more advantageous to forensic anthropologists and pathologists as they deal with decomposed human skeletons more often\textsuperscript{[3]}. Skeleton parts that can be taken into account during gender determination are: Pelvis, Frontal bone, Chin shape and brow ridges etc\textsuperscript{[5]}. Currently research in this field is not much emphasized on skull for gender detection as compared to other parts. Consideration of more features from human skull would provide more accurate results than single one. Various cranial metrics are considered in this study in the expectation of more accurate results\textsuperscript{[6]}. Computer vision, Image processing and Machine learning are widely chosen fields to provide extensive solutions to emerging research field of gender detection\textsuperscript{[1]}. Machine learning is a part of artificial intelligence that is evolved from pattern recognition and computational learning fields. It explores study of different algorithms which learn and make predictions from provided raw data as a part of training set. In this comparative study, we have considered 29 cranial metrics which are calculated manually by practitioners till date. We have provided an automated way to capture necessary points on image of human skull and then cranial metrics are calculated. Two machine learning techniques: (1) Neural Networks and (2) Support Vector Machine are applied on data set of cranial metrics. Performance of these two techniques on training and test data set is compared in this research study.

II. SYSTEM OVERVIEW
Focus of this study is the comparison of the performance of two machine learning techniques in determination of gender on the basis of cranial metrics calculated from human skull. But the main purpose of this research is to provide a solution for computerized gender detection that can be used in forensic world, criminal investigation or archeology in speeding up their process. The base for gender detection is cranial metrics data set that is calculated by the system taking inputs from user. User should have an adequate knowledge regarding cranial metrics and appropriate point locations on human skull. Here accuracy is mainly dependent upon the user’s knowledge and accuracy while selecting correct points on human skull in provided GUI which are used for calculation of metrics. Data set of cranial metrics is used as a training and test data set while applying machine learning techniques to train a machine. The basic block diagram of our proposed system for making use of Neural Networks and Support Vector Machine is shown below in fig 1.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure1.png}
\caption{Figure 1.}
\end{figure}

III. METHODOLOGY
1) Calculation of Cranial Metrics:
To characterize or compare human groups, craniometric data are regularly used. We are using this data set for the purpose of gender detection. Measurements of craniometric data are usually evaluated by vernier caliper, compass or more precisely by microscribe\textsuperscript{[2]}. Cranio metric point is a landmark on the skull from which craniometric measurements are taken. The metrics we have considered in our study are referred from HOWELLS which are mainly collected for adult individuals \textsuperscript{[4]}. Sample craniometric points we have considered are shown in fig 2, 3, 4, 5, 6, 7.

We have provided a Graphical User Interface (shown in fig 8) to users for selecting craniometric points on the image of
skull provided as an input. Skilled user with adequate knowledge of craniometric points can select those points on skull in different views. Co-ordinates of selected points will be accepted as input for further calculation of cranial metrics using two point formulas for distance calculation between two points.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

2.) Neural Networks approach
One of the techniques of machine learning is artificial neural networks (ANNs) and as the name suggests, the complex and intriguing structure of biological neural networks is the one which inspires ANN. Primarily, there are two types of learning techniques: supervised and unsupervised. ANN could use unsupervised as well as supervised learning.

Backward Prorogation of Errors, often abbreviated as BackProp is one of the several ways in which an artificial neural network can be trained. It is a supervised training scheme, which means, it learns from labeled training data (there is a supervisor, to guide its learning). To put in simple terms, BackProp is like “learning from mistakes”. The supervisor corrects the ANN whenever it makes mistakes.

An ANN consists of nodes in different layers; input layer, intermediate hidden layer(s) and the output layer. The connections between nodes of adjacent layers have “weights” associated with them. The goal of learning is to assign correct weights for these edges. Given an input vector, these weights determine what the output vector is.

In supervised learning, the training set is labeled. This means, for some given inputs, we know (label) the desired/expected output.

In BackProp Algorithm, initially all the edge weights are randomly assigned. For every input in the training dataset, the ANN is activated and its output is observed. This output is compared with the desired output that we already know, and the error is "propagated" back to the previous layer. This error is noted and the weights are "adjusted" accordingly. This process is repeated until the output error is below a predetermined threshold.
Once the above algorithm terminates, we have a "learned" ANN which, we consider is ready to work with "new" inputs. This ANN is said to have learned from several examples (labeled data) and from its mistakes (error propagation). This is exactly what we are using in our system for gender detection.

3.) Support Vector Machine approach

In machine learning, support vector machines (SVMs, also support vector networks) are supervised learning models with associated learning algorithms that analyze data used for classification and regression analysis. Given a set of training examples, each marked for belonging to one of two categories, an SVM training algorithm builds a model that assigns new examples into one category or the other, making it a non-probabilistic binary linear classifier. An SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall on.

In addition to performing linear classification, SVMs can efficiently perform a non-linear classification using what is called the kernel trick, implicitly mapping their inputs into high-dimensional feature spaces.

We found that our dataset is not linearly separated and hence binary linear classification can’t be used. We decided to use Gaussian Kernel SVM or Radial Basis Function. The Gaussian kernel computed with a support vector is an exponentially decaying function in the input feature space, the maximum value of which is attained at the support vector and which decays uniformly in all directions around the support vector, leading to hyper-spherical contours of the kernel function. The SVM classifier with the Gaussian kernel is simply a weighted linear combination of the kernel function computed between a data point and each of the support vectors. Here is how the dataset would look in 2D fig 9.

IV. ASSUMPTIONS

There are few assumptions that we have made during this study which are necessary to state as it has impact on performance of the proposed system. One such key assumption is that user of the proposed systems is having adequate knowledge of craniometric measurements. When GUI is provided to the user for cranio metric points selection, then points selection must be most accurate to get the accuracy in the result as well. Another worth mentioning assumption in this research is that the skull image provided as an input is specific to one or two human groups. There is a possibility of ambiguity when multiple human groups data set is considered for training a system. It may reduce the accuracy of the system as region wise male and female skull might be similar.

V. PERFORMANCE AND RESULT

1.) Cranio metric Measurements (Sample Data):

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Cranial Metric</th>
<th>Abbreviation</th>
<th>Sample Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Maximum cranial breadth</td>
<td>XCB</td>
<td>322.5034</td>
</tr>
<tr>
<td>2.</td>
<td>Maximum frontal breadth</td>
<td>XFB</td>
<td>268.5041</td>
</tr>
<tr>
<td>3.</td>
<td>Bimaxillary breadth</td>
<td>ZMB</td>
<td>258.0392</td>
</tr>
<tr>
<td>4.</td>
<td>Nasal breadth</td>
<td>NLB</td>
<td>69.0163</td>
</tr>
<tr>
<td>5.</td>
<td>Bilfrontal breadth</td>
<td>FMB</td>
<td>277.5040</td>
</tr>
</tbody>
</table>

Table 1. Here in Table1, We can seen sample values of few cranio metric measurements those have been calculated by using two-point distance formula.

2.) Results:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Machine Learning Technique</th>
<th>Accuracy (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Training Data Set</td>
</tr>
<tr>
<td>1.</td>
<td>Neural Network</td>
<td>82</td>
</tr>
<tr>
<td>2.</td>
<td>Support Vector Machine</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2. As shown in the Table 2, though Support Vector Machine technique worked really well while training the system, but as it turnout that Neural Network really did well for test data set. Both the supervised learning techniques could be different in manner.

VI. CONCLUSION

In this paper a system for gender detection using image processing and machine learning is presented. Human skeleton serves as the most important evidence during criminal investigation as it helps in determining age, gender, etc. A variety of body parts can be used to determine this but we are using the skull. The GUI which we have provided can be used by the medical practitioners or the anthropologists to select particular points on skull images which can be obtained from any sources such as X-ray, CT scan or MRI. Then the trained machine can be used to detect gender with the data provided after processing the image to give output according to the accuracy as mentioned earlier. The use of this system serves as a form of second opinion to the medical practitioner and thus is an approach by which more precision may be acquired.

VII. FUTURE SCOPE

Since this kind of study is one of its kind in its field, there is a lot of scope of extension in this direction. We are providing a GUI and the user has to manually select points on the image to calculate cranial metrics, instead of this we can automate the whole process by using advanced image processing techniques to programatically calculate all metrics without user intervention. Also, here we have calculated only 29 parameters but we can extend this to incorporate more parameters for better results. Furthermore, other parts (such as the pelvis) apart from the human skull can be considered for gender detection and the combined results can be used to eliminate any ambiguity. During our research we have come across some facts which help us conclude that there are a lot vital features that can be derived from the skeleton and one of
this is the determination of the human race to which the body belongs.

VIII. REFERENCES


