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## ANALYSIS OF FACIAL CHARACTERISTICS

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**Abstract:** Recently, physiognomic evaluation of human face has been widely considered in computer based visual applications. This paper presents a facial character analysis algorithm and its application to a person. This algorithm has 3-stages: Initially, face is detected from images with Viola-Jones algorithm and then crucial facial distance measurements are measured with Geometric based facial distance measurement technique. Finally, measured facial distances are evaluated with Physiognomy science to interpret characteristic properties of the person based on nose-forehead, mouth-chin and eyes-cheeks facial measurements. The simulation results show that performed facial character analysis reveals important information about the character of the experimented person.

**Keywords:** Facial character analysis, Geometric based facial distance measurement, physiognomy, Viola-Jones algorithm.

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### Introduction

Physiognomy deals with character analyzes by interpreting physical properties of the body and face. Especially examining the face features reveal crucial information about the character of the people. Facial character analysis based on facial features are widely used in a variety of areas such as fraud detection and criminal judging applications. The proposed algorithm for facial character analysis consists of three key stages: Human face detection, facial distance measurements and physiognomy based interpretation.

Face detection is the first stage of the facial character analysis. In the literature, a number of promising algorithms have been proposed. Initial work of Viola-Jones aimed to developing an algorithm to only detect frontal faces [1-2]. This forms a basis for the succeeding Viola-Jones algorithms which are able to detect faces from various angles and profiles. Rotation invariant neural network based 3D face detection algorithm proposed and experimented on a wider range of face images than Viola-Jones algorithm [3]. Even though this work shared a number of commonalities with Viola-Jones algorithm, its face detection speed and accuracy were lower. It was stated that the Viola-Jones algorithm required less detection time compare to these algorithms although the amount of scanning time was same [3]. While the key reason for Viola-Jones algorithm being faster is the implementation of a boosting algorithm called Ada-Boost, the Cascade classifier improves the correct face detection rate of Viola-Jones algorithm [12]. These are the motivations behind selecting Viola-Jones algorithm for face detection in this work.

After detecting the face, the second stage of the facial character analysis is to obtain facial distance measurements. In this term, one of the most effective technique which is Geometric based facial distance measurement technique preferred to use for this research. Recently, Valstar et al. have stated that Geometric based techniques provide higher accuracy in facial measurements than appearance based techniques [14]. One of the earliest Geometric based techniques was proposed by Kanade and tested on 16 facial images which showed

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that the accuracy of the facial measurements was 75% [15]. Brunelli and Poggio modified Kanade's Geometric based technique and examined it on 35 facial images which yielded 90% recognition accuracy [16].

Finally, physiognomy based interpretation of the measured facial distances is performed to comment on the character of the person. One of the earliest physiognomic interpretation of human characteristics was studied by Bell and his colleagues [17]. In this research, 10 faces were recognized and each face was divided into 32 regions. A further physiognomic interpretation technique was developed by Wells, divided the face into three key regions; eyes-forehead, nose-cheeks and mouth-chin. He measured width, height and length differences of each facial parts for facial characteristic interpretation [18]. In this research, Wells' approach will be used for facial distance measurements interpretation.

In the rest of the paper, Section 2 reviews the Viola-Jones algorithm used for face detection. Section 3 presents Geometric based facial distance measurement technique and Section 4 analyses facial characteristic of a person based on the physiognomy science. Simulation results are presented and analyzed in Section 5 and finally the paper is summarized in Section 6.

### Proposed Facial Character Analysis Algorithm

The proposed facial character analysis algorithm has four key stages as shown in Figure 1. In the first stage, images are taken from camera, and then at the second stage, face is detected from the taken image by using Viola-Jones algorithm. At the third stage, facial distance measurements are taken from the detected face. Finally, at the fourth stage, these distance measurements are interpreted by using physiognomy science.

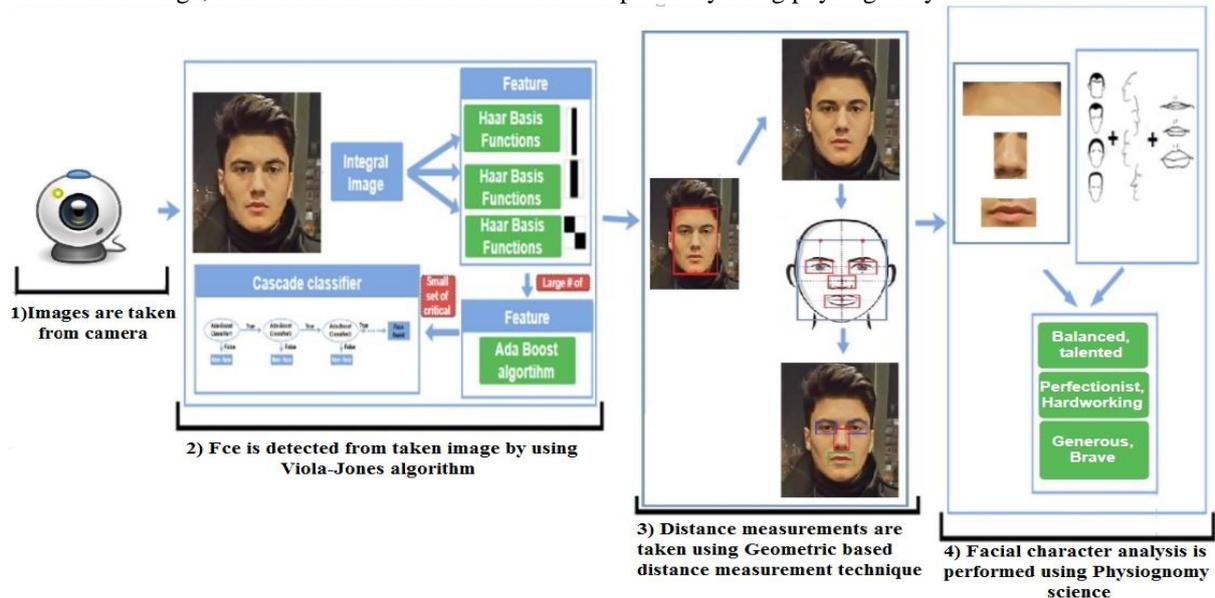


Figure 1. Proposed facial character analysis architecture

This section presents a brief review of Viola-Jones algorithm considered for face detection.

#### Haar-Like Features

Viola-Jones algorithm initially divides the taken image into rectangles and extracts features of each rectangle located all over the image. Later, based on the intensity of each rectangle, a color shade (light or dark) is assigned. Generally, located rectangles cover two, three or four rectangles in itself as shown in Figure 2.

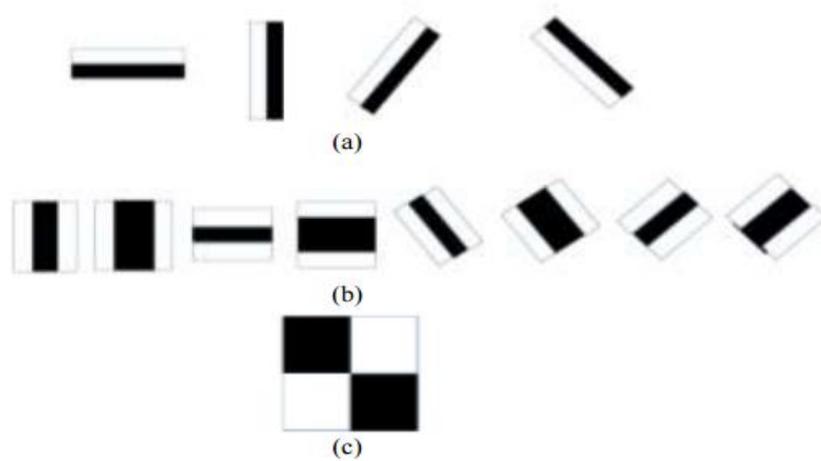


Figure 2. Rectangle based feature collection with a) Two rectangles, b) Three rectangles, and c) Four rectangles

The overall value of two rectangles with one light and dark, for instance, is the difference between the sums of the features in each rectangle. Figure 3 shows the two and three rectangles located at the eyes region having different intensities.



Figure 3: (a) is The Original Image, (b) Shows The Feature Extraction With Two Rectangles (c) Shows The Feature Extraction With Three Rectangles for The Eyes Region.

### Integral Images

After extracting features with Haar-Like, the next step is to sum up the features in each rectangle and finally the all rectangles on the image. Sum of the features in each rectangle can be determined as:

$$s(x_i, y_j) = s(x_{i-1}, y_j) + i(x_i, y_j), \text{ for each } j \quad (1)$$

where  $i$  is the indices of  $x$  and  $y$  axis and  $s(x_i, y_j)$  is the current sum of features,  $s(x_{i-1}, y_j)$  is the previous total sum, where  $s(x_0, y_j) = 0$ , and  $i(x_i, y_j)$  is the each partitioned area of the rectangle where  $y_j$  is constant.

Finally, total number of features can be found as:

$$ii(x_s, y_j) = ii(x_s, y_{j-1}) + s(x_s, y_j) \quad (2)$$

where  $ii(x_s, y_j)$  is the sum of the features in the rectangles with the terminal value  $x_s$  and  $y_j$  is the  $j^{th}$  rectangle,  $ii(x_s, y_{j-1})$  previous iterative sum, and  $s(x_s, y_j)$  is the total number of the features for the image.

### Ada-Boost Algorithm

After summing up features in allocated rectangles, Ada-Boost algorithm label them as weak or strong candidate for being possibility of part of the desired object. This algorithm requires a threshold value to distinguish weak and strong candidates.

### Cascade Classifier

In this part of Viola-Jones algorithm, Cascade classifier assess each candidate labelled with Ada-Boost algorithm as strong or weak. There are two possibilities for each candidate; either each of them will satisfy requirements of all stages or fail at a stage. This means that candidates passing all the stages leads to face detection. This process is illustrated in Figure 4.

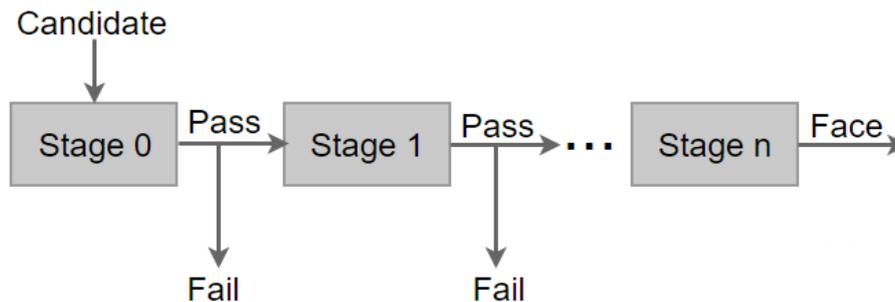


Figure 4. Elimination process of each candidate

### Facial Distance Measurements

After detecting face, the next step is to measure facial distances of the face components leading important information about character of a person. This part of the paper reviews Geometric based facial distance measurement technique.

### Geometric Based Facial Distance Measurements

Recognized face is transferred to a coordinate system and face parts such as eyes, nose, and mouth are covered with boxes.

### Distance Measurements for Eyes

Figure 5 illustrates how measurements for the eyes are obtained.

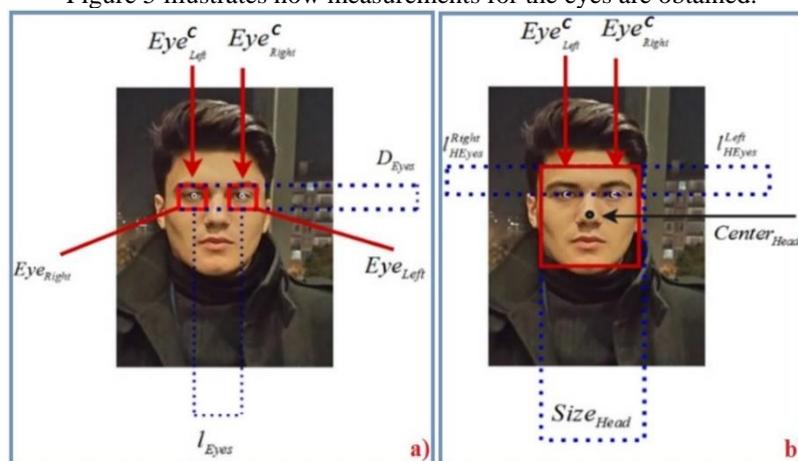


Figure 5. Schematic face representation of eye distances

In Figure 5(a), the terms  $Eye^C_{Left}$  and  $Eye^C_{Right}$  are center of the left and right eyes,  $Eye_{Left}$  and  $Eye_{Right}$  are  $x$  and  $y$  coordinates of the eyes,  $D_{Eyes}$  is the distance between eyes' centers,  $l_{Eyes}$  is the distance between the eye centers,  $l_{HEyes}$  is the distances between the upper border of the face and center of the left and right eyes,  $Size_{Head}$  is the size of the face in the rectangle and  $Center_{Head}$  is the selected center for the detected face.

The exact coordinates of the eyes are calculated as:

$$Eye^y_{Right} = Eye^y_{Left} = Center^y_{Head} + l_{HEyes} - \frac{1}{2} Size_{Head}$$

$$Eye^x_{Right} = Center^x_{Head} - \frac{1}{2} l_{Eyes}$$

$$Eye^x_{Left} = Center^x_{Head} + \frac{1}{2} l_{Eyes}$$

(3)

Eyes related two distances are;

1.  $U1$  – Average ratio of the distances between the top border of the face and center of the eyes.
2.  $U2$  – Average ratio of the distances between the eyes.

The measurement of these two ratios are made according to the size of the face rectangle ( $Size_{Head}$ ). The ratios for the eyes measurements are determined as:

$$U1 = \frac{1}{N} \sum_{i=1}^N \frac{l^i_{HEyes}}{Size^i_{Head}}, U2 = \frac{1}{N} \sum_{i=1}^N \frac{l^i_{Eyes}}{Size^i_{Head}}$$

(4)

where  $l^i_{HEyes}$ ,  $l^i_{Eyes}$  and  $Size^i_{Head}$  parameters calculated for the  $i^{th}$  sample, and contains total  $N$  samples.

Therefore, the coordinates of the eyes are obtained as:

$$Eye^y_{Right} = Eye^y_{Left} = Center^y_{Head} + Size_{Head} \left( U1 - \frac{1}{2} \right)$$

$$Eye^x_{Right} = Center^x_{Head} - Size_{Head} \left( \frac{1}{2} U2 \right)$$

$$Eye^x_{Left} = Center^x_{Head} + Size_{Head} \left( \frac{1}{2} U2 \right)$$

(5)

These coordinates allow to determine two dimensional approximate position of the eyes.

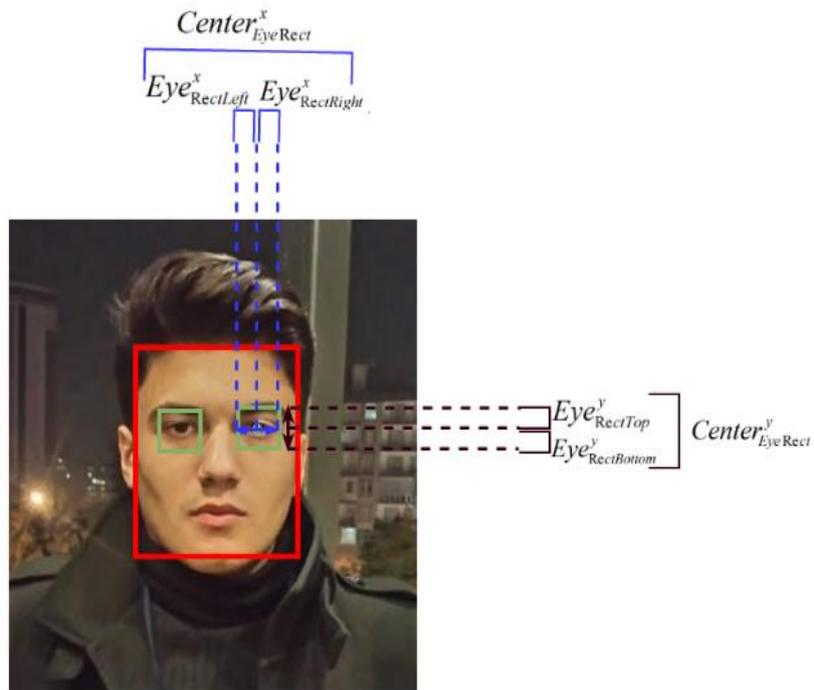


Figure 6. Configuration of the eye coordinates

#### Distance measurements of nose, mouth and forehead

Coordinates of the nose, mouth and forehead must be determined for facial character analysis. The coordinates for the center of the nose are;

$$Center^x_{Nose Rect} = (Nose^x_{RectLeft} + Nose^x_{RectRight}) / 2 \quad (6)$$

$$Center^y_{Nose Rect} = (Nose^y_{RectBottom} + Nose^y_{RectTop}) / 2 \quad (7)$$

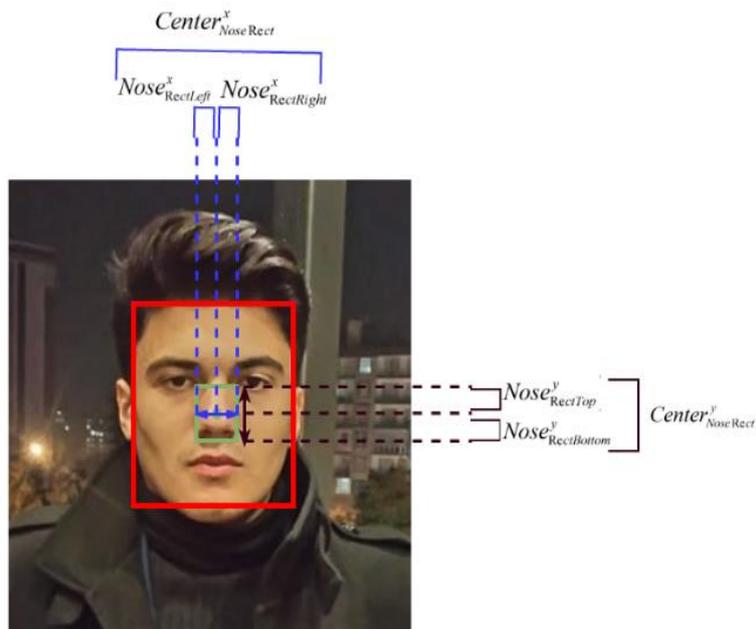


Figure 7. Configuration of the nose coordinates

To specify the coordinates of the mouth, similar process for the nose is performed. Figure 8 shows specification of the mouth coordinates.

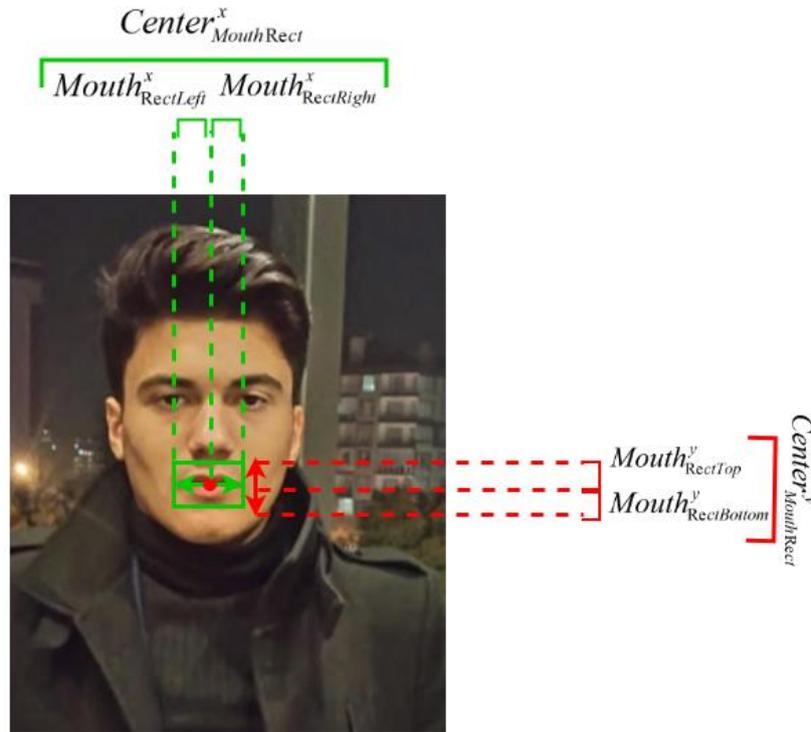


Figure 8. Configuration of the mouth coordinates

Coordinates for the mouth are calculated as:

$$Center^x_{HeadRect} = \left( \frac{Head^x_{RectLeft} + Head^x_{RectRight}}{2} \right)$$

(8)

$$Center^y_{HeadRect} = \left( \frac{Head^y_{RectBottom} + Head^y_{RectTop}}{2} \right)$$

(9)

Finally, forehead measurements with respect to the specified eyes coordinates and center of the head are calculated as:

$$Center^x_{HeadRect} = \left( \frac{Head^x_{RectLeft} + Head^x_{RectRight}}{2} \right)$$

(10)

$$Center^y_{HeadRect} = \left( \frac{Head^y_{RectBottom} + Head^y_{RectTop}}{2} \right)$$

(11)

$$A = \left( Centre^y_{EyeRect} - \left( \frac{Eye_{RectHeight}}{2} \right) \right) - \left( Center^y_{HeadRect} - \left( \frac{Head_{RectHeight}}{2} \right) \right)$$

(12)

$$F_O = \frac{A}{Head_{RectHeight}}$$

(13)

where  $A$  is forehead distance measurement and  $F_O$  is used to find forehead ratio. Figure 9 shows the related parameters for the forehead distance calculation.

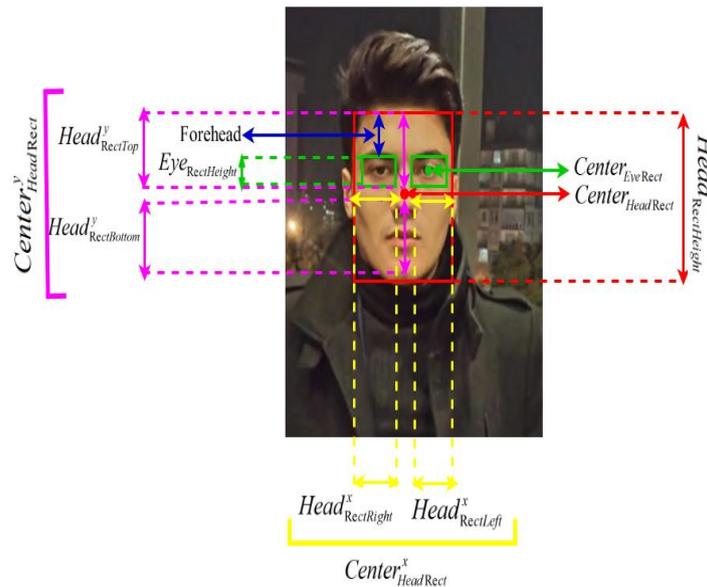


Figure 9. Forehead distance measurement calculation

### Physiognomy Based Facial Character Analysis

At the last stage of the facial character analysis algorithm, physiognomy science comments on character of the person by evaluating the corresponding facial distance measurements. Table 1 labels the facial measurements used for physiognomic base character analysis.

Table 1. Facial distance measurements and their labels

Facial feature distance measurements	
Label	Facial parts
d1	Centre of left eye, left border of left eye
d2	Centre of left eye, right border of left eye
d3	Centre of left eye, top border of left eye
d4	Centre of left eye, bottom border of left eye
d5	Centre of right eye, left border of right eye
d6	Centre of right eye, right border of right eye
d7	Centre of right eye, top border of right eye
d8	Centre of right eye, bottom border of right eye
d9	Centre of nose, left border of nose
d10	Centre of nose, right border of nose
d11	Centre of mouth, left border of mouth
d12	Centre of mouth, right border of mouth
d13	Centre of mouth, top border of mouth
d14	Centre of mouth, bottom border of mouth
d15	Eye_height, center of head, head_height

As can be seen from Table 1, to determine physiognomic interpretation, 15 facial distance measurements all related to eyes, nose and mouth are obtained and then corresponding measurements are classified for each facial measurement as can be seen from Figure 10.

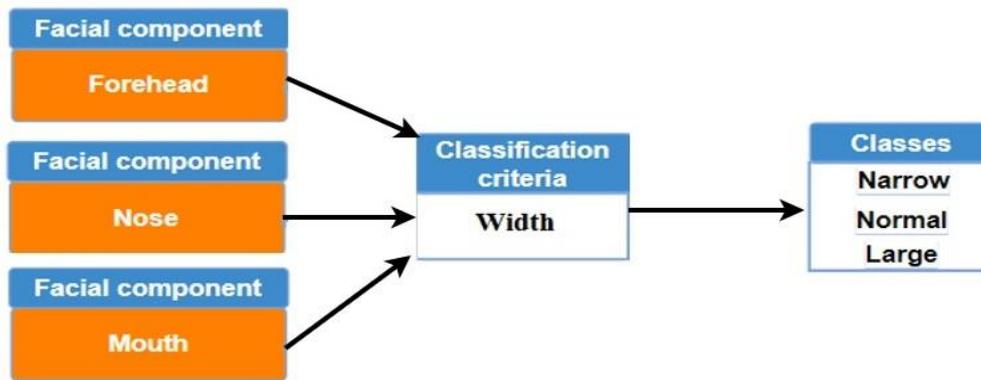


Figure 10. Physiognomy based classification of facial measurements

The classification of facial measurements lead to physiology-based interpretations shown in Table 2.

Table 2. Physiognomic interpretation of facial parts

Classes	Physiognomic interpretation
Wide forehead	Intuitive, strong imagination
Normal forehead	Balanced, talented
Narrow forehead	Very careful, punctual and strong mathematical skills
Large nose	Dominant character, social and loving to work
Narrow nose	Perfectionist, hardworking
Large mouth	Generous, brave
Narrow mounrh	Prefers to talk less and clear, conservative

Based on the facial distances, forehead, nose and mouth are categorized as narrow, normal and large as shown in Figure 11.

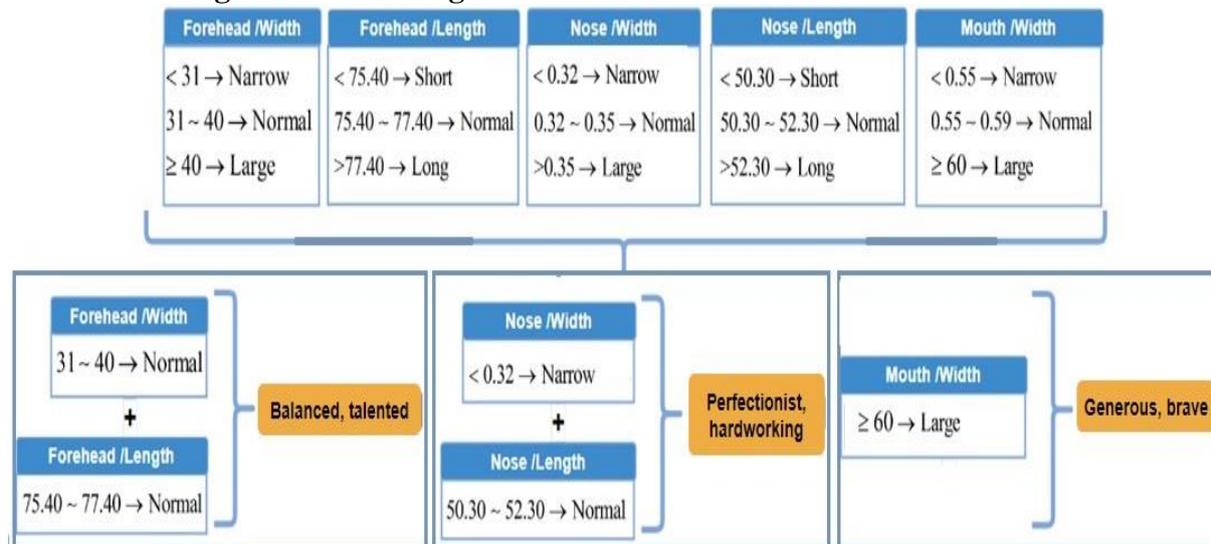


Figure 11. Categorization of the facial distance measurements

## Simulation Results

The simulation is conducted on one person and corresponding facial measurements for eyes, mouth and nose are given in Table 3.

Table 3: Facial distance measurements for eyes, mouth and nose

Facial parts	Distance Ratio
Left eye_c1	0,53
Left eye_c2	0,52
Right eye_c1	0,51
Right eye_c2	0,52
Left_nose	0,32
Right_nose	0,31
Left_mouth	0,6
Right_mouth	0,62
Upper_mouth	0,23
Lower_mouth	0,22
Forehead	0,23

After having the facial distance measurements, physiognomy science assesses these measurements to reach a decision about the character of the person as shown in Figure 13.

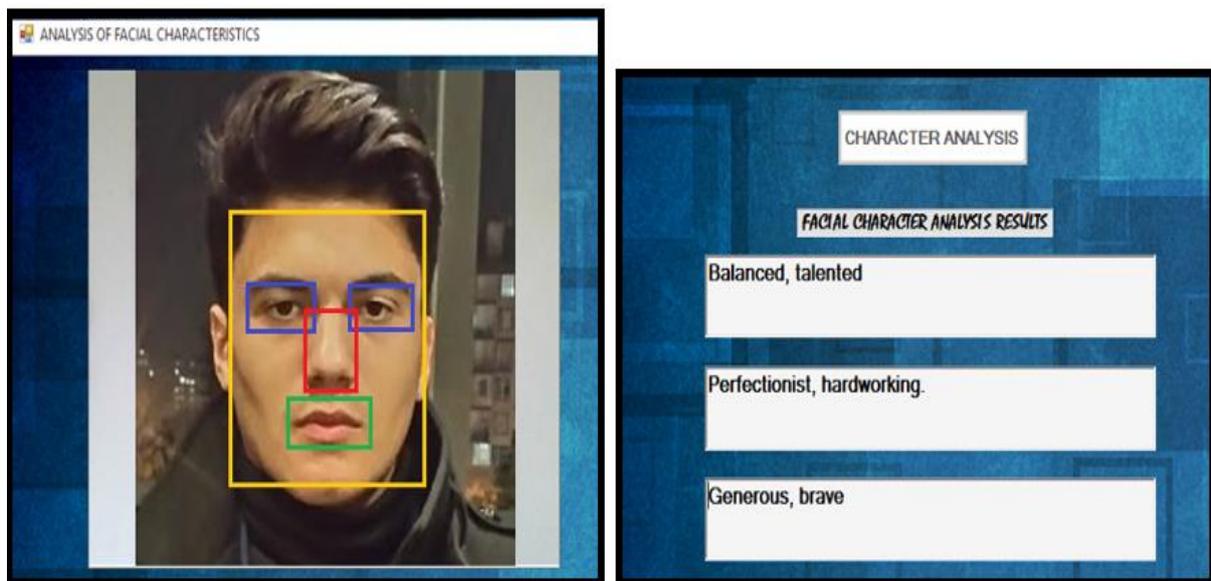


Figure 12. Facial character analysis result

This application was performed in a simulation environment and it is expected that character analysis result might vary based on the amount of the external effects.

## Conclusion

In this paper, the proposed facial character analysis algorithm is introduced and implemented. Initially, Viola-Jones algorithm is used for face detection, then important facial distance measurements are taken using Geometric based facial distance measurement technique. Finally, measured facial distances are evaluated with physiognomy science to interpret characteristic properties of the person. In the future, reliability of this character analysis algorithm will be analyzed extensively on more people and with more trials. **Then, based on the analysis results, the algorithm will be improved and applied to humanoid robots.**

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