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Face Recognition: Is It a Match?

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Abstract : Most facial recognition computer systems, including two-dimensional and three-dimensional systems, follow a basic algorithm. The algorithm consists of analyzing nodal points. Nodal points, in this case, are specific pixels on the face highlighting various facial features. These points combined are called a faceprint. Once the computer creates a faceprint for a captured face, it will try and match it to a face in the database. However, there is no guarantee that computers will be correct.

During this research, the objective was to determine the probability that a novel GUI-based software program can match a subject's captured facial photograph to the same subject's photograph in a database, and to determine a facial recognition system's accuracy. Two images of a voluntary sample of subjects were acquired. One set of images' Sum Of Weighted Ratios (SOWR) value was saved to the program's database and the second set acted as the captured images. The SOWR values were determined with internodal distances, ratios and weighted ratios. To decrease bias, a simulation was performed with a sample size of 10% of the population. An in-depth analysis of the average, standard deviation and matched pairs T-Test was performed to determine the significance of the difference in SOWR values. (Ideally, the difference of the two SOWR values of each subject should equal 0). Once statistical significance existed for a match, the expected value, or probability, of finding a match using the GUI-based software program with a margin of error was calculated to be 45%.

INTRODUCTION

Face recognition is the technique that allows people and computer systems to interpret and understand human faces. The face is an important part of an individual's self-image, a means of identification of humans, and plays a large role in social interactions, psychological processes and domestic security. Although it may seem simple at first, this is still not a well-understood process overall. Both biological scientists and computer scientists have an interest in face recognition capabilities. Since people's faces are different and yet similar, biological and technological systems involved in face recognition must have the ability to pull out a face from its surroundings. Once it is recognized that the object being observed is a face, the next step is to identify the person to whom the face belongs. The types of facial recognition strategies used in most facial recognition systems are two-dimension recognition which usually uses a frontal image of a face, and the more advanced three dimensional recognition which gathers information from three dimensions of a face and converts it into a two-dimensional model. Both methods have become increasingly popular as new research enhances their efficiency and accuracy.

There is currently more interest in face recognition technology than in other identification methods used a few years ago. Before facial recognition became a primary identification technique, as it is today, there were fingerprint identification and iris scans. These methods are still used, but face recognition has been proven to be an easier means for identification and in some cases, more effective. Today, several facial recognition systems in security cameras are used to identify individuals in crowded areas, such as train stations and airports, because they do not require physical contact with human subjects. Because a facial recognition system runs through a computer application, the only piece required is an image of a face, preferably from the front. Once the camera captures the image and the process begins, the system uses an algorithm to compare and match the image against a collection of known faces in a database. One of these systems has been developed by a company known as Visionics, based in New Jersey. They created a software program that can pick out a two dimensional image of a person's face from a crowded area and completely remove it from the scene. It then compares it to other stored images, but for the software to work correctly, it must know what a regular face looks like. A face has definite distinguishable features. Visionics states that these definite features are nodal points. There are approximately eighty nodal points on a human face. A few of the internodal points measured by this two-dimensional program are the distance between the eyes, width of the nose, jaw line, and the width of mouth. After the software has measured the points, it creates a sequence of numbers that represents that face. This code is called a faceprint. With this software, only fourteen to twenty-two nodal points are needed for it to finish the recognition process and find a match (Bonsor and Johnson). On the other hand, three-dimensional systems allow computer programs to go beyond nodal points measured from the front of the face. If a side view image of a person is taken, then specific curvatures of the face can be measured. These include the eye sockets, nose and chin. The system does this by putting the face into a three-dimensional grid while also measuring other nodal points. Then it follows an algorithm to convert this three-dimensional image into a two dimensional image to match the images in the database. However, in the process of finding a match, neither two-

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dimensional nor three-dimensional programs completely remove the probability of obtaining false positive images, or images that are claimed to be a match by the computer system but are not.

Facial recognition systems are widely known to posses several weaknesses that hinder their effectiveness and accuracy. For example, in two-dimensional systems, a program requires a facial image to be looking directly at the camera with little or no change in light or facial expression; any shift in angle of the face or variation in facial features that the algorithm does not include can completely alter the results of the program. Because it is difficult to achieve such a controlled environment, two-dimensional facial recognition tends to create a significantly large amount of false positive images. One inherent problem in facial recognition systems concerns whether the computer recognizes what it is looking at as a face. If a program is unable to recognize the image as a facial photograph, then nodal points and their distances cannot be input into the algorithm. This usually occurs when images are extremely blurry and of poor quality. Unfortunately, many security cameras make face recognition difficult by capturing such images. In these situations, some programs simulate the lack of clarity by using a Gaussian blur, a filter that removes fine image detail, on its database images ("Gaussian Blur"). Even with a programmed blur, there is still much intensive research required to get computers to recognize and process faces as humans do.

In this project, the objective is to calculate the probability that a captured image will be matched to its respective image in a database, and to determine a facial recognition system's accuracy. The program is based on an algorithm that uses nodal points and internodal distances to create a value unique to each facial photograph. The algorithm will be programmed with Java Swing components to generate Graphic User Interphase (GUI) software. After the values are saved to the database, the captured photo's unique value will be matched to the closest values in the database. The objective is to determine with a high probability that a match will be found within a reasonable margin of error. An in-depth statistical analysis will be run on the data to determine the probability and in turn, the accuracy of the GUI-based facial recognition program.

The study of face perception has increased our understanding how humans and computers alike interpret faces. Because it is becoming increasingly prominent, face recognition experiments are being used to provide technologically advanced security systems as well as in other useful applications. Faces are important to each individual and to human society. Research must continue to further the understanding of how faces are recognized.

EXPERIMENTAL PROCEDURES

Collection of facial photographs: Two images of each subject were obtained from a sample population on a voluntary basis with approximately the same number of females and males; the first set of images acted as a database and the second will acted as the captured images.

Developing GUI-based software program: Using Java Swing, computer code was written to capture nodal points A-L selected by user (See Table 1). Internodal distances were measured, ratios were calculated and then the ratios were weighted (See Table 1). Weightings were based on significance of ratios to the face (ie. eyes most significant, mouth next significant, and nose least significant). The ratios were added together resulting in a Sum Of Weighted Ratios. SOWR values were calculated and saved to the database either by plotting nodal points on an image or by importing coordinates of nodal points from an Excel spreadsheet (See Figures 1 & 2). SOWR values were searched for in the database either by plotting nodal points on a captured image or by providing the system with a previously calculated SOWR value (See Figures 3 & 4). The database SOWR values were exported to an Excel spreadsheet for statistical analysis, and in the case of an error deleted from the database.

Table 1

Nodal Point	**Location**	**Distances**	
A	Left outer canthi	[A,B]	[A,G]
B	Left inner canthi	[B,C]	[D,G]
C	Right inner canthi	[A,D]	[B,H]
D	Right outer canthi	[E,F]	[C,I]
E	Midpoint of inner canthi	[F,G]	[B,G]
F	Tip of nose	[H,I]	[C,G]
G	Junction of the philtrum and vermillion border of upper lip	[A,H]	[G,J]
H	Left nasal ala	[D,I]	[K,L]
I	Right nasal ala		

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J	Center of the bottom of the vermillion border of lower lip		
K	Left corner of mouth		
L	Right corner of mouth		

Ratios			Weighted Ratios		
[A,B] / [B,C]	[A,D] / [E,F]	[A,G] / [B,G]	([A,B] / [B,C]) * 33	([A,D] / [E,F]) * 22	([A,G] / [B,G]) * 11
[A,B] / [A,D]	[A,H] / [B,H]	[D,G] / [B,G]	([A,B] / [A,D]) * 32	([A,H] / [B,H]) * 21	([D,G] / [B,G]) * 10
[B,C] / [A,D]	[D,I] / [C,I]	[G,J] / [K,L]	([B,C] / [A,D]) * 31	([D,I] / [C,I]) * 20	([G,J] / [K,L]) * 9
[A,B] / [K,L]	[A,H] / [B,G]	[G,J] / [E,F]	([A,B] / [K,L]) * 30	([A,H] / [B,G]) * 19	([G,J] / [E,F]) * 8
[B,C] / [K,L]	[D,I]/ / [C,G]	[G,J] / [F,G]	([B,C] / [K,L]) * 29	([D,I]/ / [C,G]) * 18	([G,J] / [F,G]) * 7
[A,D] / [K,L]	[A,H] / [A,G]	[K,L] / [H,I]	([A,D] / [K,L]) * 28	([A,H] / [A,G]) * 17	[(K,L] / [H,I]) * 6
[A,B] / [H,I]	[D,I] / [D,G]	[K,L] / [E,F]	([A,B] / [H,I]) * 27	([D,I] / [D,G]) * 16	([K,L] / [E,F]) * 5
[B,C] / [H,I]	[B,H] / [B,G]	[K,L] / [F,G]	([B,C] / [H,I]) * 26	([B,H] / [B,G]) * 15	([K,L] / [F,G]) * 4
[A,D] / [H,I]	[C,I] / [C,G]	[E,F] / [F,G]	([A,D] / [H,I]) * 25	([C,I] / [C,G]) * 14	([E,F] / [F,G]) * 3
[A,B] / [E,F]	[B,H] / [A,G]	[E,F] / [H,I]	([A,B] / [E,F]) * 24	([B,H] / [A,G]) * 13	([E,F] / [H,I]) * 2
[B,C] / [E,F]	[C,I] / [D,G]	[F,G] / [H,I]	([B,C] / [E,F]) * 23	([C,I] / [D,G]) * 12	([F,G] / [H,I]) * 1

Data entry: The nodal points in Table 1 were plotted at specific locations for the first set of images designated as the database. The SOWR values were saved to the database with a unique ID, 001-999 (See Figure 2). The same nodal points were plotted for the second set of images designated as the captured images. The SOWR values were recorded in an Excel spreadsheet. The database SOWR values were exported into the same spreadsheet.

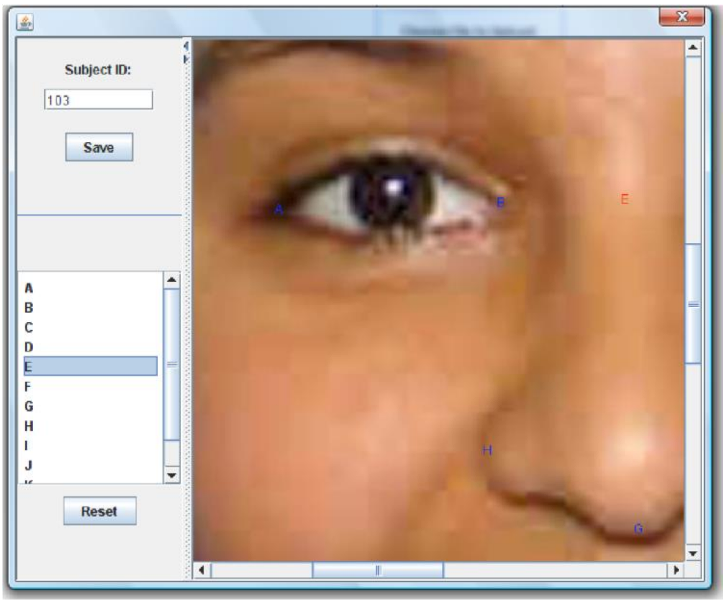

Figure 1

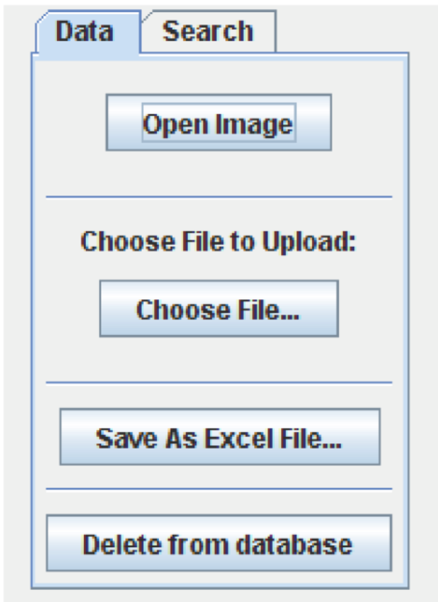

Figure 2

Used to input data.	Data entry for database.
Figure 3	Figure 4

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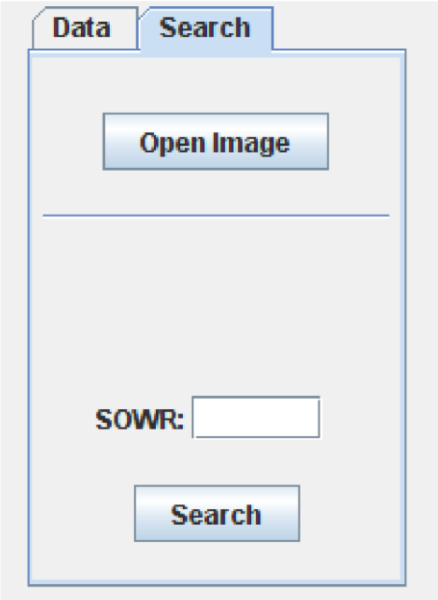
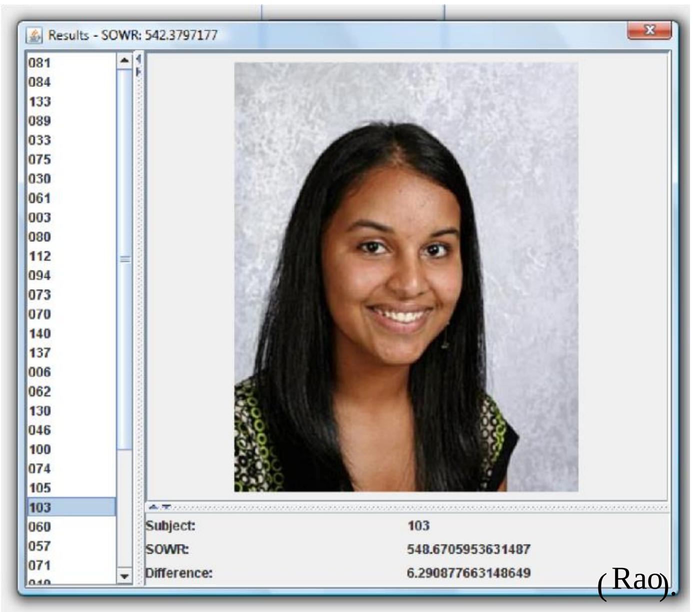
Searching for match and obtaining





(Rao).

SOWR value for captured image. Results – a match.

Analyzing SOWR values for statistical match: From the original sample population, once the data assumed approximately normal, the average difference, standard deviation and matched pairs p-value was calculated. The probability of finding a match within a margin of error based on a t-distribution of 68% confidence was also determined. To significantly decrease voluntary bias, a closed simulation of twenty trials with a sample size of ten percent of the sample population was performed. To determine the overall average difference, average standard deviation and average matched pairs p-value was calculated, and the expected value of finding a match within the same margin of error was determined.

RESULTS & DISCUSSION

During the course of this research, the problem targeted was the probability that a novel GUI (Graphic User Interphase)-based software program would match a subject's captured facial photograph to the same subject's photograph in a database. Once each image was run through this program, a unique Sum Of Weighted Ratios (SOWR, unitless) was obtained for each photograph. To compare the SOWR value of a database image to its respective captured image, the difference between the values was calculated. Out of a sample population of 144 subjects (75 females and 69 males), the average difference of SOWR values was 0.662 and the standard deviation was 18.760. The distribution of these values was put on a normal model. Based on these values the differences were put on a normal model. According to the 68-95-99.7 rule, 68% of the data must fall within one standard deviation from the mean, 95% must fall within two standard deviations and 99.7% of the data must fall within three standard deviations from the mean. Because 73% of the data fell within one standard deviation from the mean, 96% of the data fell within two standard deviations, and 99% fell within three standard deviations from the mean, the calculated differences were assessed to be approximately normal. Ideally, the difference between one subject's SOWR values should equal zero, meaning that the two images of a particular subject are actually of the same subject. This statement was supported through previous year's research and again supported with this year's sample population and a 95% confidence that the captured SOWR is equal to the database SOWR. The confidence interval used this year was (-36.859, 38.125) from the aforementioned normal model and because zero falls within this interval the data supported the null hypothesis ($SOWR_1 = SOWR_2$). From this standpoint in order to further support that no difference exists between the matched SOWR values, the paired T-test was used to determine whether the differences between the database SOWR values and the captured SOWR values were significant. The resulting p-value was 0.673 meaning that there was not a significant difference between the SOWR values the program provided.

Once it was determined that it was statistically significance that a match existed for the captured image of a subject and the database image of the same subject, a means of narrowing down the results provided in the program needed to be developed. Initially the program would display a list of the closest matches ordering from least difference in SOWR to most difference. However, results displayed in such a way would negate the purpose of a facial recognition

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system. An ideal system would find a perfect match within one photo, but because of the basics of this program a margin of error based on a t-distribution with 68% confidence interval of (0.662, 5.014) was calculated. This margin of error would provide the program with a range of SOWR values defined by one standard deviation. The resulting margin of error was 36 SOWR values (25% of the SOWR values in the database) in which a match would fall within. Out of the original population, 66 of 144 captured SOWR values, or 46%, had a match within the 36 SOWR value margin of error. However multiple simulations were performed because of voluntary bias in the sample statistics. A sample size of 14 randomly selected SOWR differences were run through 20 trials. For the first trial, a random digits sheet was used (Bock) and for the remaining trials the random number generated was used from the Texas Instrument TI-84 Plus Silver Edition. The average difference overall was 1.183 and the average standard deviation was 19.610, and because the sample population was approximately normal, each trial was approximately normal as well. The average matched pair T-test was 0.413, which again supported that there was no significant difference in the simulated SOWR values. Based on the simulation, the expected value of finding a match was 45%. This calculated expected value is the probability of finding a match using the GUI-based software program with a margin of error of 36 SOWR values.

Although the expected value of 45% may not have met ideal expectations for a facial recognition system, for a basic GUI program that was only based on an algorithm utilizing nodal points from a two-dimensional perspective, this percentage was higher than expected. Even within a scope of using nodal points alone, several areas of error exist. From variations in the location of each nodal point to the varying angles in which some of the faces presented themselves, the output SOWR values could have potentially been altered. However, facial recognition systems overall have yet to rid the majority of error which lead to obtaining false positive images. It is the combination of these systems, along with previous collected information and the human mind that will finalize a match. For example, if the system provided a list of 36 suspects, including males and females, previous information could possibly eliminate a gender and further narrow the list using age. Facial recognition systems should not replace human processes, but should rather be used as a tool in the fight for security.

CONCLUSION

Based on the statistical significance of a match for a captured image in a database, the probability a GUI-based software program finding the match is 45%.

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