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Employing Some Statistical Models in Facial Recognition

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Abstract

Face recognition is a computer vision approach that analyzes facial features to identify or verify a person's identity. it may be required to combine different biometric identification methods to improve security and recognition accuracy.
To identify an individual, facial recognition systems simulate human face understanding and recognition abilities management, there is difficulty in detecting data when using various patterns of facial image capture, especially when there is a large overlap between the patterns, it takes time to determine a person's membership, Many statistical methods have been proposed in recent years, and in this study, will be employing the Support Vector Machine (SVM), which is a statistical model for face recognition that has been used for classification and regression tasks, so this model will be compared with logistic regression, one of the significant statistical models used in prediction, classification, and facial recognition. Various methods will be evaluated with a group of datasets and varied samples (number of images); this group represented the real data, which consisted of 100 individuals. The results showed that SVM had the lowest mean square error (MSE) for the dataset, followed by LR, and all the methods reached the highest accuracy rate of 100% for facial image recognition on real data.

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1. Introduction

A computer vision approach called face recognition makes use of a digital image or video feed to recognize or validate an individual's identity. Face identification issues require a multidimensional approach that integrates expertise in computer vision and machine learning. This approach has acquired increasing traction as smartphones, security cameras, and facial recognition software have grown in popularity.

Due to the influence of facial images under different conditions, FR is both an important and difficult topic. such as managing varying lighting situations, spotting faces against crowded backdrops, detecting faces of various ages and races, spotting faces that are only partially visible, handling faces that are hidden, managing expression variation, rotation, and more.

The problem of this research is to identify a person's face from several images and when there are different shots of the same person which is a crucial problem in practical scenarios, to deal with these challenges Support Vector Machines (SVM) and Logistic Regression are two statistical methods that have been presented in recent decades for the recognition task. These methods are related to face recognition in machine learning because they can learn and extract complex patterns from the input data. [1]

Based on the principles of statistical learning theory, the SVM is one of the important statistical models used in machine learning. It can quickly and efficiently solve a large number of classification problems, and it is an excellent classifier that can generalize across different types of images and offer higher classification accuracy [2]. A decision boundary dividing the faces of various persons can be learned by SVM. The logistic regression model is a machine-learning classification algorithm. The logistic regression model is a machine-learning classification algorithm. It simulates the relationship between the dependent variable (binary) and one or more independent variables (numerical). And often employed in face recognition tasks to categorize face images into classes or generate class scores. To finish this research, we divided it into four parts: the first part contained the introduction, the second part represented the material and methods, the third part represented the discussion of results and the fourth part contained the research's conclusions and recommendations.

2. Materials and Methods

The research dataset

In the age of digital technology, facial recognition has grown to be an important pattern recognition problem [3] and an essential aspect of people's daily lives since it allows us to identify individuals by looking through the lens of a reconnaissance camera. Face recognition is a popular research area with many applications, including computer vision and pattern recognition, security systems, credit cards, passports, surveillance, and more. Facial recognition algorithms simulate human face understanding and recognition capabilities to identify an individual [4-5].

The data from the case under study is the first and most crucial phase in the face recognition process, and it is required to address this step before delving into the theoretical details of the technique. The individual images from a single experiment comprise the data for this study report, which we may demonstrate as follows:

The database was established by the AL-Mamoon College (Department of Business Administration). The database collects 1000 images from 100 students during class as shown in (Fig 1), and contains 10 different images taken for each student as shown in (Fig 2), using a digital camera to take color images from various angles.

Figure 1: The figure shows the Individuals from real data

Figure 2: The figure shows ten different images of one individual from real data

The color images for each individual are converted into gray images, with sizes ranging between 112×92 and 10304 pixels, and in this way, we can deal with a two-dimensional digital matrix m×n. As there are numbers (pixel values) inside each data matrix, these numbers which range from 0 to 255, where 0 represents the color black and 255 the color white, might indicate the brightness of the light or the precision for the clarity of the image.

Support Vector Machine

The Support Vector Machine (SVM) is one of the important models in statistical learning developed by Vladimir Vapnik in 1995. SVM is a relatively secure and flexible machine learning model that can perform linear or nonlinear classification [6], and works well with many practical problems, as a result, many attractive features of this model were introduced to solve classification problems and quickly were recently used to solve regression problems.

The key concept behind SVM is to find a hyperplane in an N-dimensional space that separates the data points of one class from those of another class with a larger margin [7], SVM is considered an ideal binary classifier due to its many characteristics such as high accuracy, fast solving, and strong generalizing ability so it is widely used in many applications, such as pattern recognition, non-linear time series predictions and financial forecasting, monitoring network design, and prediction of the properties of different engineering materials [8-11].

The algorithm of SVM has two main types of objectives: the primal objective and the dual objective. The primal objective is a geometric problem, while the dual objective is an optimization problem in a smaller space. Depending on the problem, SVM can use either the primal or dual objective.

SVM is divided into two types, the first type is known as the linear support vector machine, and the second type is known as the non-linear support vector machine which will be addressed as shown below:

1. Linear SVM: This type is called the linear support vector machine classifier, as it was used to separate linear separable data by finding the best hyperplane with a larger margin, and its principle of work is to find the ideal values for the equation of the straight line, which separates the data in the best possible way [12-13].

The idea of a linear SVM can be illustrated as follows:

If we have a set of training samples (x_i, y_i) and i=1,2,....,n, $x \in R^d$ then the feature class i can be defined by $y_i = \{1, -1\}$ we can find the linear decision limit in the form of the hyperplane of the separation of training samples as shown in the following formula [14-15]:

$$W.x_i + b = 0 \tag{1}$$

where: W vector weights, x_i input vector, b bias value

The above equation must satisfy the following:

$$g(x) = \begin{Bmatrix} y_i = +1 & \text{if} \quad w.x_i + b \geq 0 \\ y_i = -1 & \text{if} \quad w.x_i + b < 0 \end{Bmatrix} \tag{2}$$

The margin between two classes can be calculated using the following equation:

$$\text{Margin}=\frac{2}{\|w\|} \tag{3}$$

The training samples that satisfy the constraints of the following equation are called support vectors:

$$y_i(w.x_i + b) - 1 \geq 0 \quad , \forall \quad y_i = +1, -1 \tag{4}$$

And can be through linear SVM to find an ideal hyperplane interval with an increase in margin by solving the following improvement problem and by using Lagrange multiples as shown below:

$$\min L(w, b, \alpha) = \frac{1}{2}\|w\|^2 - \sum \alpha_i\big(((y_i(w.x_i) + b)) - 1\big) \tag{5}$$

Since α_i represents a Lagrange multiplier, equation (5) represents the problem of optimizing.

The problem of binary optimization can be expressed in the following equation:

$$\text{Max}\ (Q\ (\alpha)) = \sum \alpha_i - \frac{1}{2}\sum \alpha_i\alpha_j y_i y_j (x_i x_j) \quad (6)$$

where:
$\sum y_i\alpha_i = 0, \alpha_i \geq 0$
We can thus calculate the classification function (decision function) as follows:

$$f\ (x) = \text{Sign}(w^*x + b^*) = \text{Sign}(\sum \alpha_i{}^* y_j (x_i x_j)) \quad (7)$$

where: w^* the optimal weight vector for the classification which is equal to:

$$w^* = \sum \alpha_i{}^* y_j (x_i)$$

b^* Optimal bias value, Sign denotes the final decision of x belonging to any class.

2. Nonlinear SVM: This type is called the nonlinear support vector machine classifier, which was introduced by Vapnik (2000) [13]. It was used when there were problems in the classification process that prevented us from using the linear decision limit, so we used the nonlinear decision limit by expanding the area of the original feature of the linear decision limit by adding quadratic or cubic functions or by adding different combinations of features to the original space of the feature, this is known as the Kernel trick as shown in (Table 1).

SVM classifiers use kernels to provide the best decision boundary for separating classes, by projecting data into the feature space, different kernel functions can change a non-linear separable problem into a linear separable one, and then SVMs can discover the best separating hyperplane [16], because the data conversion process is not conducted explicitly, to avoid inefficiency in the calculation, which is done through kernel functions, which are applied to the original feature space, that is, it works to map data from high-dimensional areas and build a super-level linear interval of this data by projecting the original space with a dimension p into a space with a dimension r, where (r > p), and the Kernel function we can be expressed as follows [17-18]:

$$K\ (x_i, x_j) = \phi(x_i)^T \phi(x_j) \quad (8)$$

Where: φ(x) mapping function, K kernel function.

Table 1: The table shows the kinds of kernel function

Kernel Functions	Kernel Forms
Linear	$K\ (x_i, x_j) = x_i^T x_j$
Polynomial	$K\ (x_i, x_j) = (x_i^T x_j + 1)^d$
Sigmoid	$K\ (x_i, x_j) = \tanh\ (\gamma\ x_i\ x_j + a)$, where $\gamma > 0$, and $a \geq 0$
Radial Basis Function (RBF)	$K\ (x_i, x_j) = \exp\ (-\gamma \lvert x_i - x_j \rvert^2)$, where $\gamma > 0$

The problem of binary optimization in equation (6) becomes as follows:

$$\begin{aligned} \max\ (Q\ (\alpha)) &= \sum \alpha_i - \frac{1}{2}\sum \alpha_i\alpha_j y_i y_j\ \phi(x) \\ &= \sum \alpha_i - \frac{1}{2}\sum \alpha_i\alpha_j y_i y_j\ (K(x_i, x_j)) \end{aligned} \quad (9)$$

The classification function (decision function) in equation (7) becomes as follows:

$$f\ (x) = \text{Sign}(w^*x + b^*) = \text{Sign}(\sum \alpha_i{}^* y_j k(x_i x_j) + b^*) \quad (10)$$

The SVM algorithm can be summarized as follows:

- **Step 1**: Determine the X data matrix of the original image to be recognized.
- **Step 2:** Split the data into training sets (80% of the data) to train the SVM model and testing sets (20% of the data) to evaluate the performance of the trained SVM model.
- **Step 3**: Segmentation of the original matrix data through the k-means algorithm and converting them into clusters, and here the conversion is made to only two groups.
- **Step 4:** Estimating the model coefficients using the radial basis function (RBF) as follows:

$$K(xi,xj)= \exp(-\gamma|x_i - x_j|^2)$$

Where γ gamma parameter, x and y are vectors, and $|.|^2$ denotes the squared Euclidean norm.

- **Step 5:** Predict labels of the input image by using predict function, the predicted label is a number that represents the class of the input image.
- **Step 6**: The input image is compared with the rest of the images by the contribution of the original image parameters with the remaining image data to identify the corresponding image.
- **Step 7**: The original image is matched with the rest of the images by absolute value and the image belongs to the group of images where the value is zero.

Logistic Regression Model

The logistic regression model is based on the fundamental supposition that the dependent variable (Y) or response variable follows the Bernoulli distribution [19], where a binary variable has a value of one (1) and the probability (p) of the response occurring, and has a value of zero (0) and the probability of q= (1-P) when the response does not occur [20]. The response function (logistics function) can be expressed as follows:

$$f(z)=E((Y|Z) = \frac{e^{z}}{1+e^{-z}} \quad (11)$$

The classification process is dependent on the outputs of this function, which is similar to the theory of probability in that values can be either zero or one. If the function's value is equal to one, the observation belongs to the first group and if it is equal to zero, the observation belongs to the second group and here represents the variable Z independent variables, and this variable measures the sum of the contributions of all independent variables used in this model, which is known as (logit), so the input of the response function is from (-∞ to +∞) while the value of the output is between zero and one [21].

The variable Z in the case of a single independent variable can be defined as equation (12):

$$Z=B_0+B_1X_1 \quad (12)$$

In the case of more than one independent variable, that is, in the case of multiple logistic regression, it can be written as equation (13):

$$Z=B_0+B_1X_1+B_2X_2+B_3X_3+\ldots\ldots+B_kX_k \quad (13)$$

$B_0, B_1, ..., B_k$ represent the parameters of the model.

We can by transforming the logit transformation, which is used to convert formula (11) to linear form, which can be illustrated as equation (14):

$$g(z)=\text{Ln}\left[\frac{f(z)}{1-f(z)}\right]= B_0+B_1X_1+B_2X_2+B_3X_3+\ldots\ldots+B_kX_k \quad (14)$$

There are several kinds of methods for estimating the parameters of the logistic regression model, but in this study, we will focus on the most popular technique, known as the maximum likelihood method [22]:

By using logistic regression, it is possible to define the likelihood function as the probability of observing a specific pattern of occurrence of the desired attribute (Y=1) or non-occurrence (Y=0) in a sample. When Y=1 for case (i), the probability of getting the observed data is given by the term P(Xi), whereas when Y=0 for case (i), the likelihood of getting the observed data is given by the term 1-P(Xi) as [23]:

$P(Y = 1|X) = f(X)$ if Y=1

$P(Y = 0|X) = 1 - f(X)$ if Y=0

When yi follows a binomial distribution, the greatest possibility can be expressed as equation (15):

$$L(B, Y) = \prod_{i=1}^{N} \frac{n!}{y!(n!-y!)} p(x_i)^{y_i}(1 - p(x_i))^{n_i - y_i} \quad (15)$$

The above equation can be simplified:

$$L(B, Y) = \prod_{i=1}^{N} \left(\frac{p(x_i)}{1-p(x_i)}\right)^{y_i} (1 - p(x_i))^{ni} \tag{16}$$

Where:

$$Ln\left(\frac{p(x_i)}{1-p(x_i)}\right) = B_0 + B_1 x_i \tag{17}$$

By raising both sides of the equation to the natural base e, the equation becomes as follows:

$$\frac{p(x_i)}{1-p(x_i)} = e^{B_0 + B_1 x_j} \tag{18}$$

Substituting into equation (16) becomes:

$$L(B, Y) = \prod_{i=1}^{N} (e^{B_0 + B_1 x_j})^{y_i} \left(1 - \frac{e^{B_0 + B_1 x_j}}{1 + e^{B_0 + B_1 x_j}}\right) \tag{19}$$

Taking the equation mentioned above:

$$Ln(L(B, Y) = \sum y_i\left(B_0 + B_1 x_j\right) - n_i Ln\left(1 + e^{B_0 + B_1 x_j}\right) \tag{20}$$

The LR algorithm can be summarized as follows:

- **Step 1:** Determine the data matrix X of the original image to be identified.
- **Step 2:** Segmentation of the original matrix data through the k-means algorithm and converting them into clusters, and here the conversion is made of only two groups (0,1), i.e., a group containing the number zero and the other group containing the number one to form the response variable Y.
- **Step 3:** Estimating the parameters of the original image by generalizing the variable Y.
- **Step 4:** Build a model of the original image entered and calculate its logarithm.
- **Step 5:** The input image is compared with the rest of the images by the (contribution) of the original image parameters with the remaining image data to identify the corresponding image.
- **Step 6:** The image with a lower Euclidean distance is the one that matches the original image when it comes to comparing it with the other images and the following formula illustrates the Euclidean distance:

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$

Comparison Criteria

To distinguish between various facial patterns, a set of criteria can be used. Some of these criteria are discussed below:

1.Accuracy rate: This criterion is used to evaluate the performance of different methods, and the comparison between the best methods in recognition and its formula can be calculated as follows [24]:

$$\text{accuracy rate} = \frac{\text{Number of correctly recognized faces}}{\text{Total number of faces}} \times 100\% \tag{21}$$

2.Mean square error: The mean square error used to compare the models in the classification of facial patterns and can be calculated as follows [25]:

$$M.S.E = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 / n \tag{22}$$

3. Discussion of Results

The Support Vector Machine SVM was used with the logistics regression LR to compare an experimental set of data and different sample numbers (small, medium, large), i.e., number of images to be identified were chosen. To gain insights into the performance of the two methods under varying conditions to evaluate their performance in facial recognition, note that we have used the MATLAB programming language, the results of the real data group can be explained as follows:

Different sample numbers were selected to compare the methods, (small, medium, large), and for small samples (75,150) Images were selected medium samples were selected (300, 400) images, and for large samples were selected (800,600) images and the accuracy rate ACC was calculated as well as the mean squares error MSE for the three methods for comparison and table (3) shows the accuracy rate on real data using the SVM with LR.

Table 2: Comparison of the accuracy rate (ACC%) on the real data

N / Methods	75	150	300	400	600	800
SVM	100	100	100	100	100	100
LR	100	100	100	100	100	100

We can observe through the results in (Table 2) above the high accuracy rate ACC which reached 100% for both methods used as shown in (Fig.3), and equal to their values despite the different numbers of the samples used, and this indicates that not all methods are affected by the increase in the sample numbers. Where we note here their efficiency in real data in terms of high accuracy and for all sizes of samples.

Figure 3: Results of correct recognition from the real data

Table 3: Comparison of the MSE on the real data

N / Methods	75	150	300	400	600	800
SVM	0.087558	0.25459	0.10993	0.18648	0.085289	0.006324
LR	0.13063	0.19346	0.13267	0.13224	0.091936	0.1584

The MSE values in (Table 3) show for the real data from both SVM and LR, we discovered that the effects of increasing sample numbers on each method differ, and even though we were able to observe the superiority of the Support Vector Machine SVM by obtaining the lowest MSE value, and even when different sample numbers were used in comparison to another method, followed by Logistic Regression.

4. Conclusions and Recommendations

4.1. Conclusion

In this research, we employed the Support Vector Machine SVM with the logistic regression model LR to compare their performance in facial recognition of the data used in this research. Using these techniques will simplify the learning process while improving the system's overall functionality, the face recognition system can more effectively deal with and achieve better classification accuracy for facial images with several images and different shots of the same person. The results showed the efficiency of the Support Vector Machine (SVM) algorithm gave the best result by attaining the lowest value of MSE in small samples (75), medium samples (300), and large samples (600,800) followed by the Logistic Regression (LR) algorithm, and the LR algorithm attaining the lowest value of MSE in small samples (150) and medium samples (400), and also we observe that both SVM and LR give a high rate of accuracy in all the cases of sample numbers on the real data by giving 100% accuracy.

4.2. Recommendation

1. Applying other classification methods and comparing them with the methods used in this research to find out the best in the facial recognition process.
2. Utilizing the same algorithms for face recognition on a different set of data with various sample numbers, comparing the outcomes of the algorithms for the groups, and choosing the best group.
3. Depending on the results obtained in the accuracy of facial image recognition, government departments (Civil Status Department, Passport Directorate, airports, banks, security services, etc.) can use the programs used in this research, as this framework will help identify people through a digital image or video clip

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توظيف بعض النماذج الاحصائية في التعرف على الوجه

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المستخلص

التعرف على الوجوه هو اسلوب رؤية حاسوبية يقوم بتحليل ملامح الوجه لتحديد هوية الشخص أو التحقق منها. قد تكون هناك حاجة إلى الجمع بين طرق تحديد الهوية البيومترية المختلفة لتحسين الأمن ودقة التعرف.
لتحديد هوية الفرد، تحاكي أنظمة التعرف على الوجه فهم الوجوه البشرية وإدارة قدرات التعرف، هناك صعوبة في اكتشاف البيانات عند استخدام أنماط مختلفة من التقاط صورة الوجه، خاصة عندما يكون هناك تداخل كبير بين الأنماط، يستغرق الأمر وقتا لتحديد عضوية الشخص للتعرف على الفرد، وقد تم اقتراح العديد من الأساليب الإحصائية في السنوات الأخيرة، وفي هذه الدراسة سيتم توظيف آلة دعم المتجهات (SVM) وهي نموذج إحصائي للتعرف على الوجوه تم استخدامه لمهام التصنيف والانحدار، لذلك سيتم مقارنة هذا النموذج مع الانحدار اللوجستي وهو أحد النماذج الإحصائية الهامة المستخدمة في التنبؤ والتصنيف والتعرف على الوجه. سيتم تقييم الطرق المختلفة مع مجموعة من مجموعات البيانات وعينات متنوعة (عدد الصور) ؛ تمثل هذه المجموعة البيانات الحقيقية ، التي تتكون من 100 فرد. أظهرت النتائج أن SVM كان لديه أدنى متوسط مربع خطأ (MSE) لمجموعة البيانات ، يليه LR ، ووصلت جميع الطرق إلى أعلى معدل دقة بنسبة 100٪ للتعرف على صورة الوجه على البيانات الحقيقية.

معلومات البحث

تواريخ البحث:

تاريخ تقديم البحث:19/2/2024
تاريخ قبول البحث:12/4/2024
تاريخ رفع البحث على الموقع: 31/12/2024

الكلمات المفتاحية:
آلة المتجه الداعم، الانحدار اللوجستي، التعرف على الوجه، تمييز الانماط، مصنف SVM

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