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Twins and Similar Faces Recognition Using Geometric and Photometric Features with Transfer Learning

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Abstract: Twins recognition and identification is one of the important challenges in the field of image processing. The strong similarity between identical twins makes it hard to distinguish the twin from his/her sibling. Similarities come from biometric, geometric, and photometric features. In biometric patterns, the fingerprints found to be identical in some cases, geometrically, the twins' faces rarely differ which confuses people. Photometric features are very close to each other even though they rarely success in twins' recognition. We tackle this challenge by a model for twin's face recognition (FR) where our solution is based on deep transfer learning in terms of residual neural networks including two VGG16 trained networks, which are considered to be one of the powerful and deeply learned neural networks. For comparison purposes, we check other approaches to solve the twins' problem including iris, fingerprints, and lip corners. The data used was collected from Google which is a challenge. Data contains 4-pairs of twins with the 17-different position for each one which produces 5×2×17 (170) different images. Collected images were used for comparisons between features. Results show that geometrical features gave 85% of success while photometric features gave 96%. By hybridizing geometrical and photometric features together, the results reach 98% of accuracy. Biometric measures, in this research, prove the superiority of deeply transferring learning over traditional methods. The newly achieved method could be replaced to assist authentication systems that fully depend on biometric features.

Keywords: Artificial Intelligence, Machine Learning, Transfer Learning, Deep Learning, Geometrical Features, Photometric Features, Face Recognition, Biometrics, Image processing

1. Introduction

Face Recognition (FR) is considered an important biometric field in the Artificial Intelligence (AI) domain. There are several Machine Learning (ML) algorithms have been used to tackle the problem challenges on facial recognition models [1], [2], [3]. The need to detect and identify a person's face when tensions happen is critical. Recently, the surveillance systems are widely used to translate the images of specific zone into recorded video, which can be utilized in mass conflicts between individuals [4], [5]. When conflicts result in public and/or private authorities' destruction, policemen and security agents follow up recorded videos, if exist, to identify the responsibility of destruction. Biometrics have been widely used in several applications. They depend on their suitability to user application and her/his convenience. Fingerprint, face, and iris are the most widely used [6], [7]. Figure 1 shows the most widely used biometrics, which is adapted from [8].

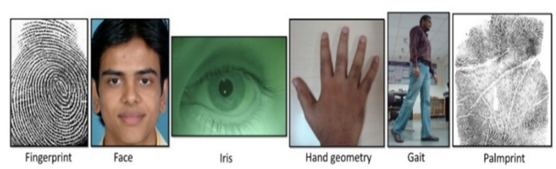

Figure 1. Biometric modalities that are most widely used in several applications from [8]

There are potential efforts to deploy the use of facial recognition for assisting the authorities to cover the mission of conflicts. Moreover, it will help the authorities of public safety to find specific wanted people like suspected terrorists, missing children, and wanted criminals [9]. The main two phases to execute the facial recognition process are the face detection and the face recognition [6]. In the following sections, we introduce a brief description of each phase.

A. Face Detection Phase

The face detector is responsible to identify if the image part is a face or not. Therefore, a segmentation process is applied to the image. The segmentation process will separate the whole image frame into two parts. The first

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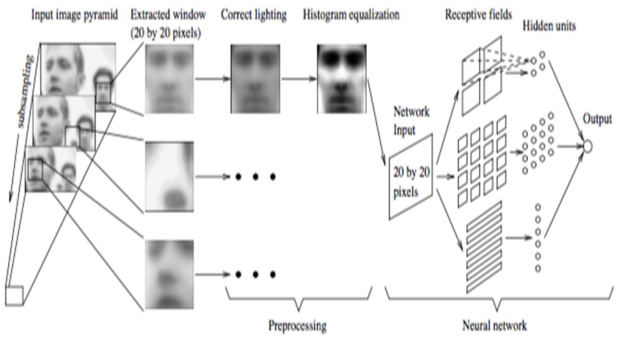

Figure 2. Face detection and blurring in digital image processing [14]

part contains only human faces, which is done by training the background (clutter). While the other part is isolated from the face window in part one. Human-face may differ for the same person considerably respect to any factors like skin color, facial expression, and age. Furthermore, the process of identifying the person by using FR systems also suffers from several complicated issues; such as the qualities of input image, the different lighting conditions, the possibility of partial occlusion and disguise, and the geometries [10]. Therefore, typical detection face methods must detect human faces under different image circumstances. To achieve this goal, a classification process should be taken place [11]. The classification is performed when a set of human faces are collected, and the detector is binarily trained so that it can decide if the image segment is taken from a face or not. With a huge and firm dataset, the accuracy of the detector would be good so far that it can easily detect the faces in the class of images. Recently, the most efficient deep learning method is the Convolutional Neural Networks (CNN), which used to get up to 99% rate of accuracy or more. After identifying the face in any image, a face localization task aims to add a bounding frame around the detected face with (x, y), and the face size that is represented by width and height on the faces found. In summary, the process of face detection is performed with three main stages: Pre-processing, Classification, and Localization. These stages are clarified in Figure 2, where the pre-processing stage evolves to minimize the variability found in the image segment based on a specified standard algorithm for cropping and light fixing. The same procedure will be applied to the face segments, which are isolated from the current image [12], [13].

In the classification step, a powerful classification algorithm is applied to determine if the image segment is a face or not. In this case, Support Vector Machine (SVM) is used [15]. Further, the Algorithms of Artificial Neural Network (ANN), and Deep Learning are widely used [16]. Recently, Convolutional Neural Networks (CNN) as deep learning is used for classification due to their high accuracy [17], [12]. In the localization step, the face is localized by a boundary XY-Window showing its position in the image by Position Scale Orientation Illumination (PSOI) technique [12]. Figure 3 shows the general taxonomy for graphical hierarchical representation of face detection methods.

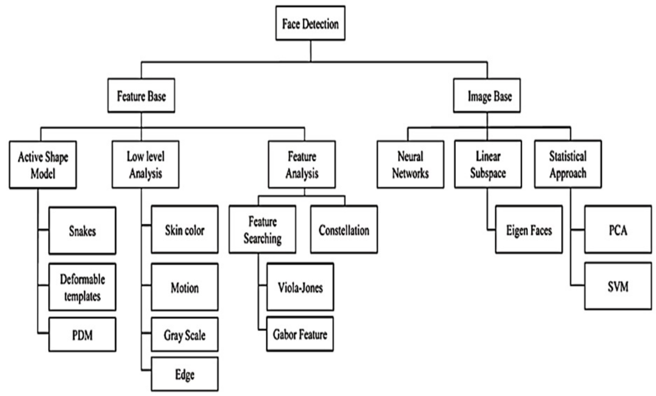

Figure 3. Face detection methods adapted from [18]

B. Face Recognition Phase

Two famous approaches are used in the recognition process of FR domain, which are: Geometrical based (Parametric Based) and Photometric (Feature Based) [19]. In geometrical face recognition, the correlation between facial landmarks, or the spatial configuration of the extracted features is determined. The key geometrical features of recognizing the human-face are the eye's shapes and their color, the nose geometry, the mouth and the distances between facial landmarks. The set of distances and polygonal features are the main input to the strong classifier or algorithm, which recognizes the individuals. Even though the geometrical features are important and worthy, sometimes they fail in recognition especially in twin's recognition case. As the interest of researchers in face recognition is continuous, there are many algorithms have been developed. Principal Component Analysis (PCA) using Eigenfaces, Linear Discriminate Analysis and Elastic Bunch Graph Matching based on Fisher-Face algorithm are the most three FR algorithms that have been investigated in the literature for face recognition purposes. Figure 4 shows the basic human face geometry [13].

In Figure 5, the main steps in face recognition are performed based on geometrical features that are extracted from the human face. A grid template is used to estimate the correct values corresponding to a specific person, and to assist the classification process [13].

The second and most efficient features for face recognition are the photometric features, which are non-geometrical ones. The image in this case is converted into statistical values, and then these values are used as input features for face recognition. It is usually used to recover the object's shape from several images taken under different lighting conditions, which are specified by a gradient map. This map is composed of an array of the surface normality. Figure 6 shows a photometric normalization for an image. The image

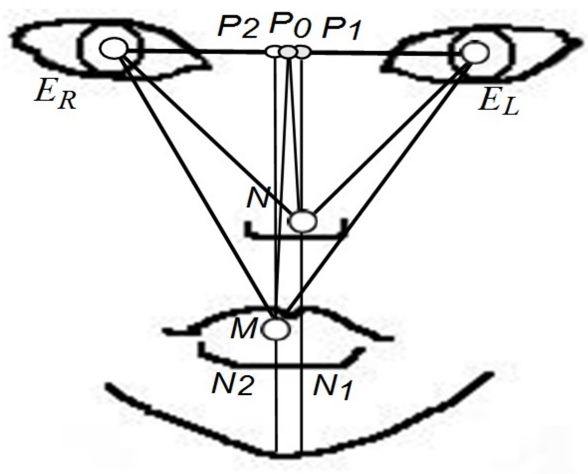

Figure 4. Frontal view of geometrical face model adapted from [13]

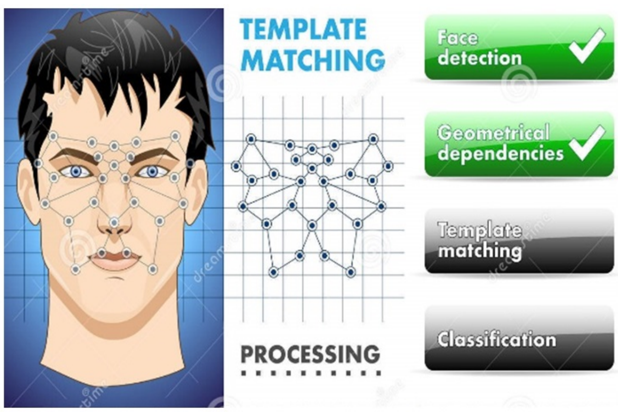

Figure 5. Face recognition steps based on face geometry with template matching technique [20]

at each stage is converted to black and white or grayscale depend on its application [21].

Several types of features or descriptors could be extracted, which usually used in classifications. These features include HOG, LBP, SURF, KAZE, BLOCK and Pixel Neighborhoods [22], [23]. The essential contribution of this research is to improve the adequacy of face recognition frameworks by managing false positives via utilizing model vulnerability. The investigation of proposed model focuses on the use of deep learning by using multiple deep learners. Then, transfer their learning into face recognition for strong and firm recognition to the human-facial pictures especially in situations where intra-class varieties are poor and low.

The rest of the paper is set up as pursues the problem definition in Section 2. Section 3 presents the main background of the adapted deep transfer learning method. Then, the foundation of literature review is introduced in Section 4. The proposed developed model for the twins face acknowledgment is expounded in Section Experiments and

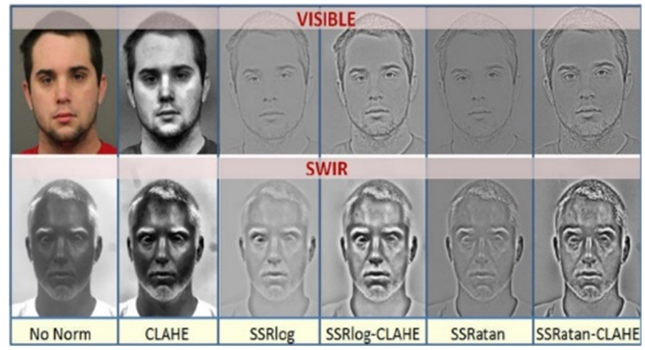

Figure 6. Process of photometric normalization applied on visible and SWIR (1550 nm) imagery. In columns 3 and 5, the image of the face converts to be obscuring local texture with over-saturated one. In column 4 and 6, the SSR application harnessed by CLAHE is used to reduce over-saturation, and raise the contrast of local textures [22]

results' discussion are committed to the obtained outcomes and talks in Section 6. The last section concludes and closes the paper with some future directions.

2. Problem Definition

The face recognition issue can be figured as pursues: Given info face picture and a database of face pictures of known people, how might we check or decide the character of the individual in the information picture. The problem gets more complicated when identical twins appear or look-alike existing people. Processing face recognition for identical or looks-alike people needs special attention due to high similarity in approximately all features. By looking at Figure 7, it is obvious that after cropping faces and on the same features, it is hard to know who's who in a set of faces.

Figure 7. On the left identical twin, on the right are looks alike persons [24]

3. Deep Transfer Learning

Pass on AI learning strategy where the given model is can be reused in the first phase of the model with faster work. It is a good way to see in depth where pre-programmed models are used because the first phase of PC viewing, and common language management methods are given the time and resources needed to build neural program models for these problems and large bumps provide related problems. Learning transfer is considered an important in performance improvement when the second assignment is indicated. The transfer of learning that the development of the learning of another action through the exchange of data in a related assignment has recently been taught. In any case, learning transitions are highlighted in depth or by learning given the great resources needed to plan in-depth learning models, or large data sets and to prepare in-depth learning models. Flexibility transmission can apply to in-depth learning when the model features found in the beginning task. In further teaching, we initially train a basic program for basic knowledge and practice, and then introduce key points taught, or passed on, to a targeted system that will be transferred to a targeted database and provided. This process will add to the normal if the prominent is common, which makes sense in both targeted assignments and assignments, rather than clarity in low performance. Two basic methods are used in rotation to make the installation suspended as follows: Enhance Model Approach (DMA) and Pre-prepared Model Approach (PMA). During this study, we focused on the use of PMA methodology, because it is the most widely used in deep learning. The PMA approach contains the following related development steps [25]:

- *Choose the suitable model*: The pre-trained base model is selected from the existing models. Several agencies produce models in large and challenging data sets that anyone can pick from them
- *Adapt the model for your problem*: the base trained model is to be adapted to fit the new problem. All the trained base model parts may be included in the new problem solution or part of them. The reused parts depend on the new problem environment and features.
- *Modulate model attributes*: Optionally, the model needs to be modified in the available output data for the performance of interest. The study is expected to share information on issues that show image details being used as information. It is expected to take photos or video details as information. For these types of issues, they hope to use a pre-programmed in-depth learning model for unlimited image editing and testing, for example, the ImageNet 1000 group image collection controversy.

Regularly, the exploration communities that make models for this challenge, introduce their final model to be the permissible permit for future adapts and use. These models can run over days or weeks to maintain on today's devices. By downloading these models, the image model is legally integrated into the newer models. The Microsoft Resnet model, the Google Inception model and the Oxford VGG model are three examples of this type of model. This system was successful because the photographs were made on an unlimited number of photographs and usually required a pattern to create expectations in a large number of classes, so the model should work effectively as a way of focusing highlights from the photos. Perform well in adverse conditions [26].

In addition, dynamic learning can solve the problem of conveying basic messages informatively by preparing simple language. For such problems, word implantation is adapted, which is a mapping of words into a large nonstop vector space. Further, the comparative vector representation for different words of comparable importance is used. There are productive calculations to raise awareness on this circulation terminology. The research associations commonly make pre-made models with extensive content records under general permission. Two examples of this type of model are Google's Word 2Week model and the Stanford Glove model. The models of transferable word illustration can be downloaded and integrated with the in-depth learning language models. These integrated models are used in the form of yields from the informative word interpretation or age integrated model [25], [26].

4. Literature Review

In this section, the problem of face recognition is generally addressed. Then, we focus on our target under study which is the twins face recognition. We targeted the identical twins in this study, since twins may be identical or non-identical.

A. General Face Recognition

Face acknowledgment has gotten a lot of considerations from academicians, business consistently expanding applications in observation and control, law authorization, cross fringe security, sight and sound applications, crime scene investigation and some more. With progression in innovation and a decrease in the cost of cameras (sensors), new utilizations of face acknowledgment have been predominant. Check dependent on face pictures caught through implicit cameras is utilized to enable access to individual gadgets, such as PCs and cell phones. With the advancement in face acknowledgment innovation, it is currently utilized for cross fringe security. Hong Kong-SAR fringe has the world's first drive-through face acknowledgment framework [27], [28], [29]. Shrewd Gate at Australia, US visit, and Japan visit programs additionally gather all guests' faces. Face acknowledgment is likewise utilized in stand applications to enable access to ATMs, server rooms and web-based business applications (Internet banking). In addition to that, it has discovered applications in huge social welfare programs where another client is coordinated against every single existing client to check for copies. As of now, two states in the United States (Massachusetts and Connecticut) use face recognizable proof for [6], [13], [23], [30]. Several approaches were used in face recognition as shown in Figure 8.

B. Twins Face Recognition

Authors in [32] portrayed an indistinguishable twins' recognition challenge as a very well-known problem. They contemplated this issue and manufactured a model to get a criterion to discover an answer for this issue. They made many tests to recognize the twins depending on ears shape, profile and so on. They took ears pictures, trimmed them

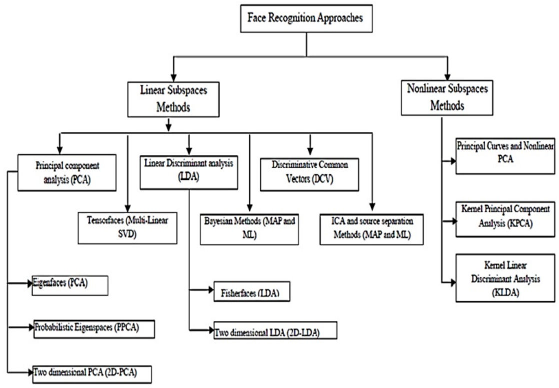

Figure 8. Face recognition approaches [31]

and did some preprocessing. Then they passed those ears pictures 'Left and Right' through different levels. These levels were goals, impediment and clamor levels, which utilized a ground-breaking capacity to dissect highlights, after they separated the ear, that was included as a vector of highlights '1 line X N segments lattice'. After that, they passed them to the KNN to assess the gathered dataset by coordinating procedure climate to determine whether both of these ears alluded to this individual or not. They applied their model on 39 twins (78 people), the outcomes of their model are considered as accomplished.

In [33] the authors proposed a strategy to construct a model to fathom the subject of what we are attempting to see, which is an amazing criterion as ready to be unraveled. Their technique was based on various stages outlined as preprocessing on pictures that include extraction, arrangement and organized confirmation. The first stage is to clear the uproarious in the picture (something that shows up in the picture and doesn't identify with the face). However, this will expand the picture rightness. The second stage is to crop the face picture centered around face marks and the lip where the mouth corner could be distinguished. The third stage is the picture highlight utilizing a few separations capacities. The last stage is to check if the existed coordination is considered as twin or not. The dataset was taken and collected from twins' day celebration held annually on the first full weekend in August in Twinsburg, Ohio.

In [34], the authors presented a psychological research for distinguishing between the monozygotic twins. Their obtained results proved the ability to distinguish twin's face with lack of negative detection factor, which is known a self-face advantage. Therefore, they speculated the visual image representation depending on the control participants of monozygotic twins. Finally, they deployed new processes based on the multi-sensory integration for enhancing their final outcomes. In [35], the authors introduced a study of distinctiveness to recognize the identical twins. Their study is performed based on three types of facial features, which are the facial marks, the MLBP and the SIFT features. They primarily use the entire face to measure the accuracy rate of the obtained results. Then, the eyes, the shape of eye-brows, the mouth and the nose as main distinguished components are further used, in order to enhance the accuracy rate of final results.

The research in [36] used the various AI methods to propose models to comprehend it in the manner that they thought it appears to be effective. A few methods were given models to explain an undertaking dependent on finger impression, and others dependent on the iris. In our day-by-day life, we manage associations to benefit from their administrations like banks. They utilized a physical part, like unique finger impression and iris, to deliver a truly solid confirmation with a significant level of productivity and exactness. These confirmation criteria must be remarkable for every individual to recognize her/him from others. An account of indistinguishable twins biometric and hereditary is fundamentally the same cause of a problem. Likeness brought about by the solid connection between twins makes a major issue in the entrance authorization process. Unique finger impression gave a low quality to perceive between twins and high precision for none.

Authors in [37] worked to solve the task based on a physical part like the fingerprint. They were aware of the strong similarity in biometric parts between twins even in terms of fingerprints. So, they took a multi-level capturing for fingerprints. The dataset used in their model contains 83 pair of twins, 83×2 equals 166 persons. They took 4 fingerprint images (left index, left middle, right index and right middle) for each person from the dataset, and 6 impressions for each finger. Finally, the total was 166 by 4 by 6 gives 3984 images. More realistic results were gained for recognition, which had supported them to get more realistic results of the recognition between twins based on fingerprints. There are three different methods were distributed for studying the twin's recognition based on the fingerprints template and the image. i) First one is non-twin imposter distribution done by testing the matching of a person with anyone else except her or his twin. ii) Two genuine distributions test the matching between the fingerprints and other fingers for the same person. iii) The last distribution is identical twin distribution and non-twin distribution, which is done by a process of testing the matching between the person and her or his sibling. The images have been used to train this model, and then to test it in order to reach an acceptable result as they are hoped. The sample was collected on 2-October-2007 at the Fourth Beijing Twins Culture Festival. In summary, Table I shows the most important research done regarding twins' recognition compared to our study.

5. Proposed Twins Face Recognition Model

A. Data Acquisition

Our data set was taken from the FASSEG (V2019) database, which is consisting of four subsets. These images are very useful for training and evaluating the default meth-

TABLE I. Comparative Experiments of Proposed Method for Recorded Results in Three Different Types of Matches

Ref.	Goal & basis considered	Algorithm	Collected database	Size	Accr.
[32]	Twins recognition with high accuracy based on ears shape data points in ears	Remove nose passed the image in multilevel to extract feature then KNN as a classifier	39 pairs of identical twins give (78 subjects)	78 sub-jects	Up to 92%
[33]	Twins recognition with high accuracy based on face & lip corners	Some distance functions	Different twin's festival using the web	N.A	Unkwn
[37]	Twins recognition based on fingerprints using multilevel	P071 algorithm with VeriFinger 6.1 SDK	October-2-2007 Fourth Beijing Twins Culture Festival	83×2×4×6 =3984 img.'s	89.5%
Our Proposed Work	Twins recognition with a high accuracy based on the entire face	Deep learning neural network, we used VGG16 with geometric and photometric features	5 pairs of twins give 10 subjects using the web	5×2×17 =170 img.'s	hybrid achieved **98%** accr.

ods of facial recognition function [38]. Three subsets, which are called frontal01, frontal02 and frontal03, are specially designed to create a front face separation. Frontal01 has 70 original RGB images, and associated masks with a labeled quotation. Frontal02 has the same 70 images' data with the most accurate written text. Frontal03 has face marks described in 150 twin words taken in different facial expressions, shapes and lighting conditions. The multipose01 is the last subset, which has more than 200 human-faces in many poses and true world masks. In all facial expressions, the earth's true masks are labeled in six categories (eyes, nose, mouth, skin, hair and background). We pointed to the details of Frontal03 that contains twin photos of the twins and the looks alike human faces, as seen in Figure 9.

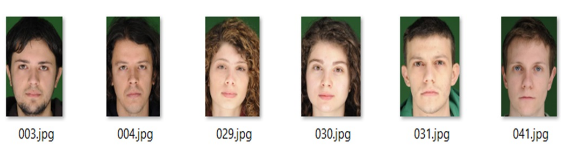

Figure 9. Sample twin and looks alike human faces from FASSEG [38]

In a nutshell, there is a short limitation for the available of twins' databases in literature. So, we try our best to find and use all the available datasets of twins. Furthermore, a data augmentation approach is deployed in order to enlarge the size of used dataset [39], [40]. Therefore, the number of used images is tripled. Practically, the augmentation process is firstly done including rotation with multiple angles (3 angles). Then, a transformation process is performed after the rotation. Consequently, the total number is increased to become 510 images. We applied more investigation and found that any further augmentation was not useful for the case of used data. Although the results were slightly affected, we repeated the experiments, and there were no major improvements in the readings.

B. Learning Model

The problem of identical twins' identification is not a straightforward classification problem, since twins cannot be discriminated based on predefined groups that may encompass all possible identical twins in the world. Also, the input of a trained classification model should be one input image, but in our case, the inputs are two images that correspond to two persons for checking identicality. Therefore, a proposed solution model for this problem should take two input images. Furthermore, deep CNN models can extract deep features from an input image, which in turn increases the ability to distinguish identical twins since the extracted features by the CNN model are assumed to be robust and discriminative.

Accordingly, the proposed model consists of two deep CNN networks that correspond to two different input face images, and they are responsible for extracting deep features. The two networks have the same architecture and the same activation functions. The extracted image features are represented through two feature vectors, one for each input image. Then, the similarity between the two output vectors is computed to distinguish between the identical twins. Figure 10 shows the main architecture of our proposed model.

Transfer learning via deep learning can be used in two ways, either transfer learning via fine-tuning (retraining) or transfer learning via feature extraction. The latter is used for classification purposes, while the former is used to employ the extracted features for another purpose, in our case it is a similarity measure.

When the transfer learning is employed for feature extraction, a pre-trained deep network is utilized as a method of feature extraction. This is carried out through the forward propagation of the input image through convolution layers and stopping before reaching the fully connected layers (classification layers) or until the last max-pooling layer. Then, taking the outputs of the last reached layer (pre-specified layer) is done as features vector.

We choose to use the VGG16 pre-trained network, two copies of the chosen network were fine-tuned using face images contained by the Frontal03 subset. When both networks are fine-tuned, their fully connected layers are chopped off to generate VGG16 feature extractors as illustrated earlier in Figure 10.

Since the size of the data set is relatively small while

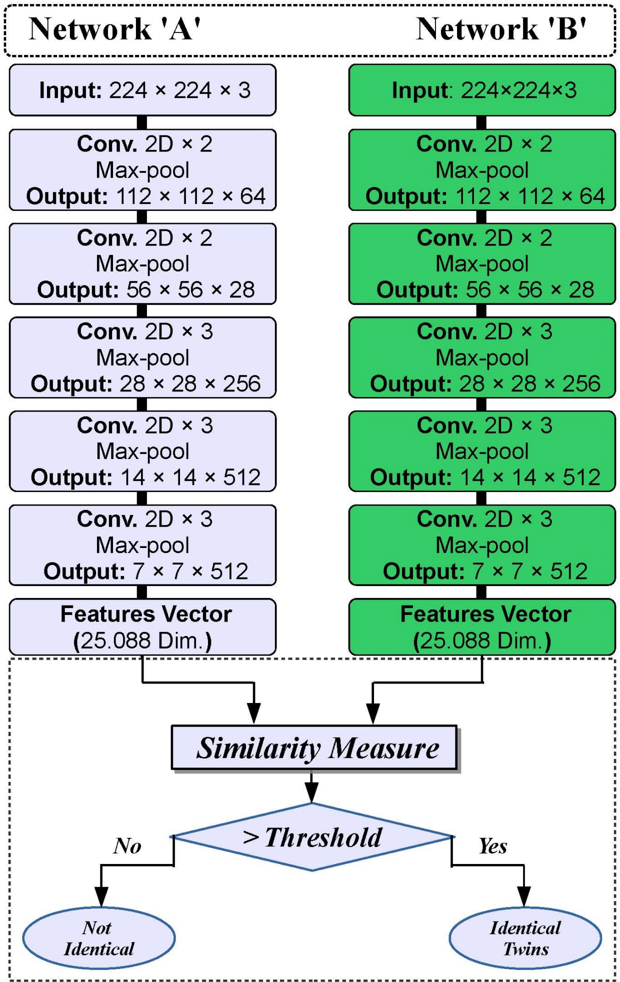

Figure 10. (TwiNet) the proposed model architecture

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	(None, 224, 224, 3)	0
block1_conv1 (Conv2D)	(None, 224, 224, 64)	1792
block1_conv2 (Conv2D)	(None, 224, 224, 64)	36928
block1_pool (MaxPooling2D)	(None, 112, 112, 64)	0
block2_conv1 (Conv2D)	(None, 112, 112, 128)	73856
block2_conv2 (Conv2D)	(None, 112, 112, 128)	147584
block2_pool (MaxPooling2D)	(None, 56, 56, 128)	0
block3_conv1 (Conv2D)	(None, 56, 56, 256)	295168
block3_conv2 (Conv2D)	(None, 56, 56, 256)	590080
block3_conv3 (Conv2D)	(None, 56, 56, 256)	590080
block3_pool (MaxPooling2D)	(None, 28, 28, 256)	0
block4_conv1 (Conv2D)	(None, 28, 28, 512)	1180160
block4_conv2 (Conv2D)	(None, 28, 28, 512)	2359808
block4_conv3 (Conv2D)	(None, 28, 28, 512)	2359808
block4_pool (MaxPooling2D)	(None, 14, 14, 512)	0
block5_conv1 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv2 (Conv2D)	(None, 14, 14, 512)	2359808
block5_conv3 (Conv2D)	(None, 14, 14, 512)	2359808
block5_pool (MaxPooling2D)	(None, 7, 7, 512)	0
flatten (Flatten)	(None, 25088)	0
fc1 (Dense)	(None, 4096)	102764544
fc2 (Dense)	(None, 4096)	16781312
predictions (Dense)	(None, 1000)	4097000
dense_1 (Dense)	(None, 16)	16016

Total params: 138,373,560
Trainable params: 138,373,560
Non-trainable params: 0

Figure 11. Process of feature extraction based on pre-trained model

the data similarity is very high, we do not need to retrain the model. All we need to do is to customize and modify the output layers according to the problem statement using the parameter adjustment. Therefore, we implement and use the pre-trained model as a features' extractor [41]. In this case, all we do is just modify the dense layers and the final softmax layer to output 2 categories instead of a 1000 output [42]. Figure 11 explains the detailed description of implementing and adjusting the parameters during the process of feature extraction based on pre-trained model.

Then, a similarity measure component is added on the top of the used deep networks with the function of computing how the two similar-looking individuals are similar to each other. The similarity between the output feature vectors is computed by using Cosine Similarity [43], [27]. The proposed algorithm has a built-in threshold value, where, if a match score would fall below this threshold, the similarity score is automatically returned as zero. Figure 12 represents the working procedure of the proposed model.

Note that the threshold value was determined by testing the proposed model uses 30 pairs of identical twins' images. For all tested pairs, we found the similarity measures were above the specified threshold value.

6. Experiments and Discussions

The performance evaluation process for our proposed algorithm is carried out through the verification of two image groups. The first group is consisting of 50 image pairs for different (nonsimilar) individuals. They were retrieved randomly using the Google search engine. The second group is for looking-similar individuals that consist of 50 pairs of twins, and they are retrieved from samples of image selected from ND-TWINS-2009-2010 Dataset [44], [45]. Images of the latter dataset were taken in natural lighting conditions indoor and outdoor. Capturing angles were varied from −90° to +90°. Also, images were taken within natural

TwiNet Algorithm:

```
        // inputs are face images of two persons
input:  face_image1 , face_image2

// extracting features
feature-vector1 =: Network'A'(face_image1)
feature-vector1 =: Network'B'(face_image2)

//measuring similarity between two faces
similarity =: Cosine-Similarity (feature-vector1,
                                  feature-vector2)

// check for identicality
if (similarity > threshold ) then
      identical twins
else
      different persons

      finish(0)
```

Figure 12. Pseudocode of proposed TwiNet algorithm

and smiling facial expression.

Meanwhile, the proposed method is implemented based on deep transfer learning using MATLAB platform at PC with Intel i7 processor and 32.0 GB RAM. In the process of testing, the task is given a pair of face images, then we verify whether both faces belong to the same person or not. The accuracy of our proposed algorithm is tested by generating the confusion matrix [46], [47]. We compute the related accuracy measures such as Sensitivity, Specificity and F1-score. The mathematical formulas for these used three measures and metrics are adapted from [40], and they are represented in the following equations:

$$Sensitivity(SEN) = \frac{TP}{TP + FN} \tag{1}$$

$$Specificity(SPC) = \frac{TN}{TN + FP} \tag{2}$$

$$F1 - score = (\frac{(SEN)^{-1} + (PRC)^{-1}}{2})^{-1} \tag{3}$$

Noted that the *Precision* (*PRC*) is computed using the following formula:

$$Precision(PRC) = \frac{TP}{TP + FP} \ , \tag{4}$$

where TP, TN, FP,& TP refer to the true positive, true negative, false positive and true positive, respectively. All tested images are preprocessed by applying the face segmentation, Adaptive Histogram Equalization (AHE) algorithm [27], and by resizing all images to (224×224) dimensions due to minimizing noise and achieving normalized contrast conditions.

A. Results and Discussion

About 100 image pairs were tested. Our proposed TwiNet model recognized 50 out of 50 image pairs as identical twins (Figure 13 shows a sample of identical twin's result), and 48 of 50 image pairs as nonsimilar persons (Figure 14 shows a sample result of nonsimilar persons). Table II summarizes the final results.

Figure 13. Identical twins recognized

Figure 14. Different persons recognized

According to the above confusion matrix, the proposed model's Sensitivity is 1.0, which reflects the algorithm robustness regarding recognizing identical twins. Also, the

TABLE II. Represents the testing confusion matrix

		Predicted	
		Similar	*Unsimilar*
Ground-Truth	*Similar*	50	0
	Unsimilar	2	48

Figure 15. Testing accuracy measures

Specificity is 96%, and *F*1-*score* is 98%. Figure 15 shows the testing accuracy measures of the proposed model.

The proposed algorithm performs up to 98% on the Twins identifications. Results also proved the robustness of our algorithm considering the variance of resolution and noise.

7. Conclusion and Future Work

We tackle the problem of twin's face recognition during our project supported by Yarmouk University in Jordan. We targeted this challenge by a model for twin's face recognition. Our solution is based on deep transfer learning in terms of residual neural networks including ResNet-50, ResNet-101, which are considered to be one of the powerful and deeply learned neural networks. This research proves the superiority of deep transfer learning over traditional methods. It reaches 98% of accuracy. The newly achieved method could be replaced and used to assist authentication systems that fully depend on biometric features.

For further research, it will be important to build and collect more data of identical twins' images in future works. Deploying new methods other than deep transfer learning could also be utilized in further studies to enhance the quality of the final results in future research.

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