Face Biometric-Based Document Image Retrieval Using SVD Features

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Abstract Nowadays, a lot of documents such as passport, identity card, voter id, certificates contain photograph of a person. These documents are maintained on the network and used in various applications. This paper presents a novel method for the retrieval of documents using face biometrics. We use trace of singular matrix to construct face biometric features in the proposed method. K-nearest neighbor approach with correlation distance is used for similarity measure and to retrieve document images from the database. Proposed method is tested on the synthetic database of 810 document images created by borrowing face images from face94 database [1]. Results are compared with discrete wavelet transform features (DWT), which is counterpart of singular value decomposition (SVD). Proposed features in combination with correlation similarity measure provided mean average precision (MAP) of 75.73% in our experiments.

Keywords Face biometrics · Document image retrieval · Singular value decomposition · Face detection

1 Introduction

Huge number of documents such as identity cards, certificates, and passports contain photograph of a person. Retrieval of such documents based on the photograph (face image) will help to search and access all documents belonging to a particular person. Such work will find its importance in offices, government

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organizations, as well as in crime branches to collect and verify information about a person.

In this paper, we propose a method for retrieving of documents based on photograph or face images. In the proposed system, initially we separate out the photograph (face image) from the query document image and then based on features extracted from the face image, other documents in the database that contain similar face image are retrieved.

The main contributions of this paper include proposing new idea for extracting features from face image employing SVD. When an image is decomposed using SVD, the singular matrix generated consists of only diagonal elements and these elements will be unique in nature. We suggest using trace of this singular matrix as a feature for the retrieval of documents based on face biometrics. The proposed method is tested using an artificial database consisting of 810 documents, and the results are also compared with discrete wavelet transform (DWT) features, which are counterpart of SVD. The rest of the paper is organized as follows: Sect. 2 discuss about the literature related to this work; in Sect. 3, we explain the proposed work in detail; Sect. 4 provide discussion about the results; and finally Sect. 5 concludes the paper.

2 Related Work

Cao [2] presented theory on singular value decomposition and its application for digital image processing. They also introduced a method for face recognition using SVD features. They treated a set of known faces as vectors in subspace called "face space," spanned by a small group of "base faces." Projection of a new image on to the base face is compared with known face images for recognition.

Nefian and Hayes [3] presented a new approach in using PCA. They applied PCA on wavelet sub-bands. They employed wavelet transform for decomposing an image into different frequency bands, and mid-range frequency subband is used for PCA representation.

Vikram et al. [4] proposed a technique for person-specific document image retrieval. They used principal component analysis (PCA) and linear discriminant analysis subspace method for face recognition. In their work, they recommended calculating the average of the face images, by normalizing the size and tagging all the documents to this average face image.

Jang [5] proposed a novel approach for face detection that employs a user-oriented language model for face detection. The proposed method works by projecting face images which represents the significant variations among known faces. They were motivated by information theory and used Eigen vectors, which are significant feature values called as the Eigen faces.

A novel Walshlet pyramid-based face recognition technique was presented by Kekre et al. [6], in which features are extracted from Walshlets applied on various levels of image decomposition. Sadek [7] presented a work describing the

applications of SVD for image processing with research challenges. This paper provides a survey on SVD-based image processing applications. It also includes new contributions using the properties of SVD for image processing applications. Keyvanpour and Tavoli [8] presented a survey on document image retrieval based on signature, logo, and layout structure of the documents. It also proposes a framework for the classification of document image retrieval approaches.

In our proposed method, initially we segment the face image from the document and then we extract features from this segmented image. For segmentation of face image, we compute the energy contributed by the connected components, and the component with highest energy is considered as face image or photograph in the document. We used the trace of the singular matrix of decomposed face image as a set of features for matching query with database documents, correlation distance metric for similarity measure for ranking and retrieval of documents.

3 Proposed Method for Face Biometric-Based Document Retrieval

We divide the process of face biometric-based document image retrieval into three tasks: In the first task, we detect and separate out photograph or face image from the query document; the second task is to extract features; and in the third, we retrieve the documents based on similarity. Following sections describe these three tasks in detail.

3.1 Photograph Detection from the Document Image

In the documents such as identity cards, passports, and certificates, portion that consists of photograph will have more energy compared to any of its other parts. This idea is to detect and separate out the face image from the document. Algorithm 1 shows the steps used for the detection of face image from the query document.

Algorithm 1: Face image detection from query document image

1. **Input:** Query document image,
   Output: Face image.
2. **Begin**
3. Convert color image to grayscale.
4. Find connected components in the image.
5. Compute energy of each connected component using Eq. (1)

$$EN_{CC} = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} |CC(i,j)| \tag{1}$$

Where, EN_{CC} is energy of connected component CC[M:N] with size M × N.

6. Photograph or Face image = Connected component with Max (EN_{CC})
7. **End**

Document containing face or photograph of person is used as an input to the algorithm. Normally, these documents are stored as color images. In preprocessing step, color document images are converted to gray scale and median filter is applied to remove impulse noise. Then, we identify connected components in the document image and compute energy of each component using Eq. (1). Connected component with highest energy is assumed as part of document image containing a photograph or face image. This component is then extracted from the document image to compute its features in the next step. Figure 1 shows sample results of face detection and extraction from document image.

3.2 *Feature Computation for Extracted Face or Photograph from Document*

Features of an image decide the performance of image analysis, matching, and retrieval results. Here, we propose SVD-based features for the retrieval of document images based on face biometrics. SVD is an algebraic tool, which can be used in various applications of image processing ranging from representation to compression of an image [4]. It allows decomposing of an image into three matrices that include a singular matrix containing diagonal elements. A square matrix is called singular, only when one of its singular values is zero. Singular values contain huge information about the image and will be unique in nature. This motivated us to use singular values as features in the proposed method. Algorithm 2 shows the steps used for constructing the feature vector.

Fig. 1 Sample result of face detection and extraction from document image

Algorithm 2: Feature computation for extracted face or photo from document

1. **Input:** Face image, **Output**: Feature Vector (FV)
2. **Begin**
3. Resize face image to 64 × 64 pixels.
4. Divide face image into four blocks as F_1, F_2, F_3 and F_4 with size 32 × 32.
5. Decompose F_1, F_2, F_3, F_4 using SVD and obtain set of singular values $\{SF_1\}$, $\{SF_2\}$, $\{SF_3\}$ and $\{SF_4\}$.
6. Store diagonal elements of four image blocks

$$Diag[1:128] = \{SF_1\}\ U\ \{SF_2\}\ U\ \{SF_3\}\ U\ \{SF_4\} \tag{2}$$

   Where Diag[1:128] holds singular values of SF_1, SF_2, SF_3, and SF_4
7. Compute Feature Vector

$$FV[1:32] = \left\{ \sum_{i=1}^{4} Diag(i,i),\ \sum_{i=5}^{8} Diag(i,i),\ \ldots,\ \sum_{i=125}^{128} Diag(i,i) \right\} \tag{3}$$

   Where, each element of 'FV' is trace of singular matrix obtained after decomposition.
8. Return FV
9. **End**

Let "F" be an extracted face image resized to 64 × 64 pixels. We divide image "F" into four blocks that gives rise to F1, F2, F3, and F4 each of size 32 × 32 pixels for obtaining features. Application of SVD on these blocks can be represented using Eq. (2).

$$F_i[32:32] = U_i \times D_i \times V_i^T,\ for\ i = 1\ to\ 4 \tag{4}$$

In Eq. (2), U_i, D_i, and V_i^T are the decomposed matrices of F_i, respectively, each with size 32 × 32. Columns of matrices U_i will be Eigen vectors of $F_i \times F_i^T$, columns of matrices V_i will be Eigen vectors of $F_i^T \times F_i$, and D_i the diagonal matrices that contains singular values. The singular values are obtained as a square root of Eigen values of $F_i^T \times F_i$, and these represent unique information about the image. Each diagonal matrix D_1, D_2, D_3, and D_4 contain 32 singular values after decomposition. Now to obtain the feature vector, trace of the matrix is computed by dividing each diagonal matrix D_i into 8 parts. The sum of diagonal elements of a matrix is called its trace and in Eq. (3), it is computed as $\sum_{i=1}^{N} Diag(i,i)$. Thus, we created a feature vector FV with 32 elements.

3.3 Retrieval of Documents

Initially we extract features using Algorithm 2 from all the preprocessed documents in the database and store these features in a file to create indexed documents. Similarly, feature vector from query document is obtained while processing the query. Then, we employ following steps for the retrieval of documents.

- Let FVDB[1:N] be the array of feature vectors of all the documents stored in the database, and FVQ is the feature vector obtained from the query document.
- Compute correlation distance value between FVQ and each of FVDB vector using (5) for document matching.

$$CorrelationDist[1:N] = 1 - \frac{(X - M_x)(Y - M_y)^T}{\sqrt{(X - M_x)(X - M_x)^T \times (Y - M_y)(Y - M_y)^T}} \quad (5)$$

  where X and Y are the feature vectors, M_x and M_y the mean of vectors X and Y.
- Apply K-nearest neighbor approach to retrieve top 10 documents using correlation similarity distance measure. Here, the documents are sorted based on computed distance values, such that document corresponding to lowest distance at the top, to retrieve top K number of documents for the user.

4 Results and Discussion

Due to unavailability of public database, we created our own database consisting of 810 document images for testing the proposed method. Database stores 30 documents for 27 persons, leading to a total of (27 Persons × 30 Documents) 810 documents with various sizes, including identity cards, passports, and certificates. Face images in the database are borrowed from publicly available database face94 [1].

Precision, recall, and F-measure are used as evaluation metrics. Precision is a measure indicating the fraction of retrieved documents that are relevant to the query; recall provides fraction of relevant documents retrieved out of total relevant documents stored in the database; and F-measure is a combined metric given by (6).

$$F - measure = \frac{2 \times Precision \times Recall}{Precision + Recall} \quad (6)$$

Figure 2 shows the sample result of document retrieval using face biometrics. The sample result shown have successfully retrieved relevant documents yielding a precision of 70% and 23.33% of recall.

For comparing proposed method with DWT, we executed 27 randomly selected queries and calculated average precision and recall considering Top 1, Top 5, Top

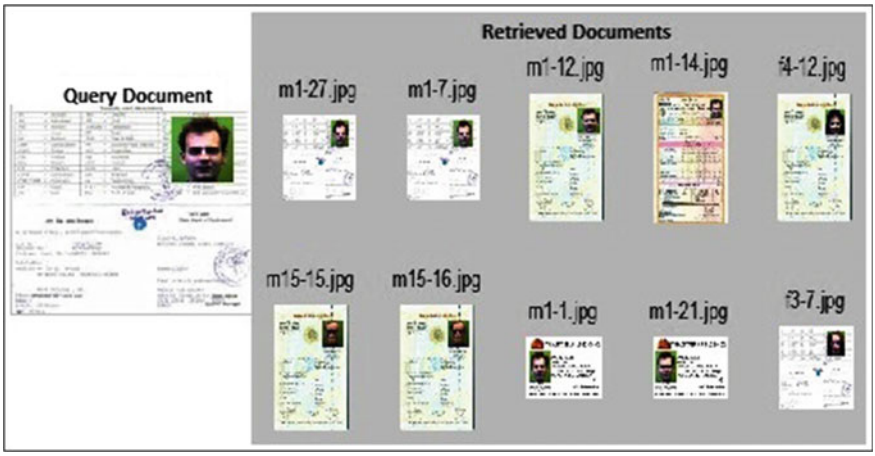
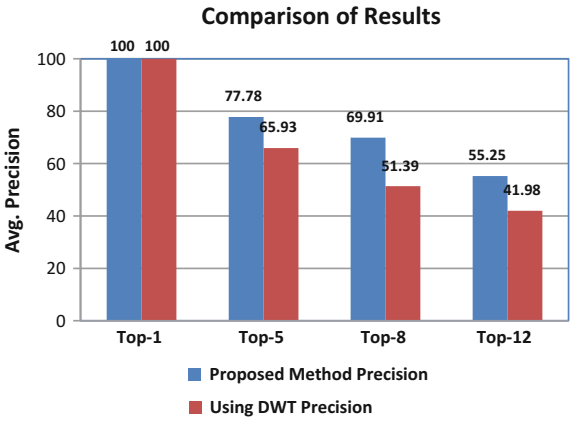


Fig. 2 Sample query document and retrieved documents

Table 1 Experimental results

Top matches	Proposed method (SVD-Based features)		Using DWT features	
	Average precision	Average recall	Average precision	Average recall
Top 1	100	3.3	100	3.3
Top 5	77.78	12.96	65.93	10.99
Top 8	69.91	18.64	51.39	13.7
Top 12	55.25	22.1	41.98	16.79
Mean values	**75.73**	**14.25**	**64.82**	**11.19**

Fig. 3 Sample query document and retrieved documents



8, and Top 12 retrieved results. Table 1 shows the tabulated results of the experiments conducted. Figure 3 shows the comparison of the results. It can be observed that proposed method provides better results compared to DWT. We have achieved mean average precision of 75.73% using the proposed method in comparison with 64.82% using DWT features.

5 Conclusion

We proposed an approach for the retrieval of documents based on face biometrics that is helpful in business offices, organizations, government agencies, etc. A new technique of using SVD-based features is proposed for feature extraction process, and correlation distance metric is used for similarity measure. The proposed method is tested and compared with DWT features on database created with 810 document images. With the proposed method, we achieved a mean average precision of 75.73%.

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