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The Biometrics System Based on Iris Image Processing: A Review

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***Abstract*—Recently, it reported that the cases of cybercrime had increased by about 13% in 2017, especially in data fraud crime, due to the poor security system. One of the solutions to this problem is by implementing a biometric system as a security platform. Biometric is a method of personal ID authentication by using human recognition using unique human biometric values such as fingerprint, voice, face, or iris. This review paper focused on the iris biometric system since Iris biometric widely used as a system for maintaining data security, such as ATM, cellular phone, etc. Moreover, the biometric has very high sensitivity and accuracy for recognition than the other. In this paper, we will review some experiments of iris recognition that was done by researchers. As a result, we will present some comparisons among several studies, including in feature extraction technique, performance, and time computation required on the matching process. From the paper review, we can analyze that a good result of iris recognition depends on the selection of the right features and the needed time computation. The use of Haar Wavelet (texture analysis) with three different iris databases showed the best performance, such as MMU (ACC = 96.44%, time = 0.34s), UTIRIS (ACC = 96.21%, time – 0.68s), and IITD (ACC = 97.14%, time = 0.64s).**

Keyword--iris recognition system, iris biometric system, iris feature extraction, iris image processing, iris authentication

I. Introduction

Biometric is an automatic identification and authentication of a human identity based on the unique characteristics in the individual. Biometric consists of two characteristics, and they are physiological and behavioral characteristics [1]. Physiological characteristic contains DNA, face, earlobe, and iris, while behavioral contains signature, voice, keystroke recognition, and gait analysis. In this paper, the discussion focused on iris image processing for recognition. Iris is one of the significant parts in a human eye that controls the size of the pupil, which this way directs the measure of light entering the pupil. It is situated behind the cornea and in front of the ens. Iris incorporated as an inner organ of the eye. The first idea of iris acknowledgment was proposed in 1987 by Flom and Safir. They proposed exceptionally controlled and non-useful condition to change the brightening with the goal that the size of the understudy in all pictures continues as before for reasonable iris division.

According to [2], [3], iris recognition technology offers the highest accuracy than another biometric recognition system. It is because of the feature of iris extraordinarily stable and not change for many years, except identical twins or even among the left and right eye of a similar individual [2]. Every human has a unique characteristic of the iris. The iris fully formed when the human in ten months old and same the duration of their lifetime. Iris recognition is an automated method by using Human-Computer Interaction (HCI). There are many kinds of real-time applications using iris recognition as authentication because iris has high accuracy and sensitivity. Iris recognition was used to secure communication and mobile commerce. So, It can prevent unauthorized access to ATM, cellular phone, and PC [4][5]. It can also help the human if they lost a personal password. Iris also becomes the other personal identification for personal access account in cellphone, ATM, etc. In this case, the conventional method will become not reliable because of it.

Some previous studies [6][7] showed several methods used for iris recognition. The researchers conducted many experiments to provide high accuracy in iris recognition. Generally, a type of iris recognition consists of 6 main stages [1]. Capturing an image with the camera is the first step in image processing. A type of camera, lighting, and several pixels affected the iris image quality. The second stage is image pre-processing, which means size, color, and light are made equal to prepare a segmentation stage. The third stage is that segmentation includes boundary detection between iris and pupil. Canny detection is the most method used to identify between iris and pupil [6]. The fourth stage is normalization. In this stage, the iris region transformed into a form like a rectangle. Then, the fifth stage is feature extraction that extracts feature from the normalize iris image and encode these feature to iris recognition. The last stage is the identification or classification of iris input with the iris database.

Usually, the primary objective of the iris acknowledgment is to accommodate a high precision from the iris database utilized in research. Each author has a trick to get the best result. In this study, we will review the selected paper and then analyze several methods used by the author to obtain a good result for iris recognition. The results of this paper can be used as a guide by other writers who will do more research on the iris detection of biometric systems.

II. Method Of Paper SelectION

There are two stages for choosing a good paper in this work, namely:

A. Search Strategies

All papers are taken in 2018, which obtained from the journal database like IEEE, Springer, and Science-direct. The author chooses its database because they have excellent and competent scientific paper publications in various fields of science technology. Furthermore, the searching article was done by entering keywords in the database like "Biometric," "Iris Recognition," "Iris Enhancement," "Iris Identification," and "Iris biometric System." The author only focuses on searching through internet technology which has an extensive network and more updated in various fields

B. *Screening Paper*

After collecting several papers, the author screened the paper with 2 criteria. First, the article used is an article published in less than 10 years. Two, evaluate and asses the content of the paper, include: relatable content between title and abstract, also contributions made by paper. To make an easier of an assessment process, we use a tabulation method to analyze each paper with some indicators like author name, year of publication, research design, contribution, or result. These indicators are used to determine the final results of the paper to review.

III. IRIS RECOGNITION METHOD

A. *Iris Database*

Analysis of image processing depends on image quality. A right quality image can increase the accuracy of iris recognition. Many kinds of iris dataset were used by some researchers to study and recognize human iris with several methods, such as CASIA Iris database [8–15], UBIRIS [16–21], Phoenix [22], [23], Indian Institute of Technology Delhi (IITD) Iris database [21], and independent measurement [2], [24], [25]. CASIA database is one of the databases that captured an image in two sessions. CASIA-Iris V3 contains a total of 22.051 iris image datasets, and this database consists of three subsets: Clear iris, iris-lamp, and iris-twins.

The UBIRIS have two variants of pictures, the first is, pictures were gathered in two distinct sessions comparing to enrolment and acknowledgment stages, and the subsequent one is, pictures caught with progressively practical commotion factor on non-compelled condition. ND 2004-2005 database utilizes an Iridian iris imaging framework for capturing the image. This is guiding a user through voice feedback to a correct position before capture the iris image. Another database is the UPOL database from Department Computer Science, Palacky University. The last, IITD database collected from the participant at IIT Delhi, India, they are a student and staff of IIT and captured by CMOS camera. This database contains 1120 images captured from 224 persons (14-55 years old). IITD database has eyelids and eyelashes. So, the segmentation process of this database is more complicated. These people are 176 males and 48 females.

B. *Pre-processing*

Pre-processing is a significant procedure in iris acknowledgment. This procedure decides the achievement of iris include extraction and acknowledgment. Iris pre-processing consists of 2 processes.

Image resizing, it means changing the image size from smallest to largest or otherwise to equal the size in a single database. Image resizing can decrease the processing time because decreasing the size of the image [1].

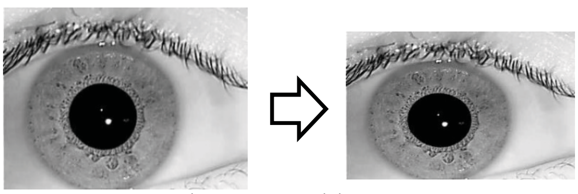
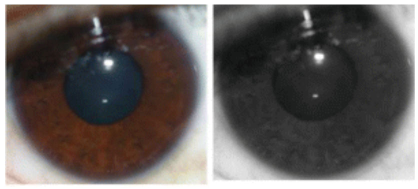


Fig. 1. Image resizing

Convert RGB to grey dataset must transform from RGB to gray or HSI color space. This way is used for multi-block transitional local binary patterns (MB-TLBP) coding [4]. Besides that, it can also be used to simplify the information on the image before it is processed further into digital image processing.



(a) (b)

Fig. 2. (a) Original image, (b) Grey Image

Image Localization, Iris image in some cases additionally capture other parts of the eye like eyelid and eyelash. So that, the iris texture gets distorted. This artifact must dispose of through the procedure of pre-processing to give high performance in iris recognition.

C. *Segmentation*

Iris segmentation is to detect every boundary of iris and pupil automatically in eye image. It is to exclude the surrounding regions. This process will determine the success of extracting the features of iris for personal identification. There are some techniques for iris image segmentation. Edge detection [10], [15], [19], [23] and Hough Transform [11-13], [16], [18], [21], [24], [25] were popular techniques for iris image segmentation.

The other segmentation methods were Geodesic Active Contours (GAC) and Daugman's Integro-differential operator [20]. GAC was developed by [3]. This strategy was dependent on the connection between dynamic forms and the calculation geodesics. A method used to advance the contour from inside the iris affected by the geometric proportion of the iris picture. The advancement of this technique found in Fig. 4. GAC can reduce Equal Error Rate (EER), eye right about 3.1%, and left about 2.48 %.

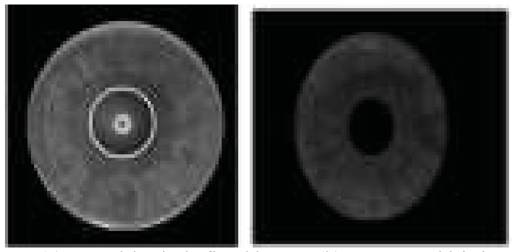
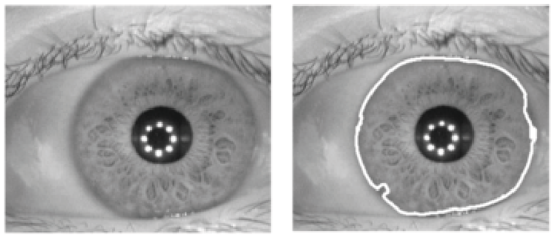


Fig. 3. (a) Inner iris circle fitted image, (b) Segmented iris image.



(a) (b)

Fig. 4. Evolution of segmentation process: (a) image original, (b) segmentation process with GAC

D. Normalization

After the segmentation process, the following stage is to change the iris part to a predefined dimensional pattern to simple in the feature extraction process. Daugman's Rubber Sheet Model is a conventional normalization method which used in iris recognition [1], [8], [11], [15], [18]–[20], [23], [25]. This method resets each point inside the iris region on a pair of polar coordinates (r, θ), where r ranges from [0.1], and θ ranges from [0.2π]. It is seen in Fig. 5. This Rubber sheet model based on (1), (2), and (3).

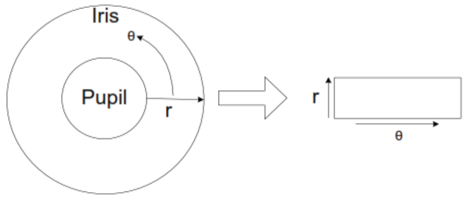


Fig. 5. Daugman's rubber sheet model

$$I(x(r,\theta), y(r,\theta)) \rightarrow I(r,\theta) \quad (1)$$

with,

$$x(r,\theta) = (1-r)x_p(\theta) + rx_1(\theta) \quad (2)$$

$$y(r,\theta) = (1-r)y_p(\theta) + ry_1(\theta) \quad (3)$$

where *I (x, y)* is the iris region image, *(x, y)* is the original Cartesian coordinates, *(r, θ)* are the corresponding normalized polar coordinates, and x_p, y_p, and x_l, y_l are the coordinates of pupil and iris boundaries along the θ direction.

This technique's limitation is there are interpolation and decimation because pixels' number far from the pupil is higher than that close to the pupil. Besides that, Han et al. 2009 [24] used a novel normalization image to solve that problem. They used the original texture to fill the pupil area. Then the normalized image can be obtained with the geometric structure. This process said as non-polar coordinate normalization. It can be seen in Fig. 6.

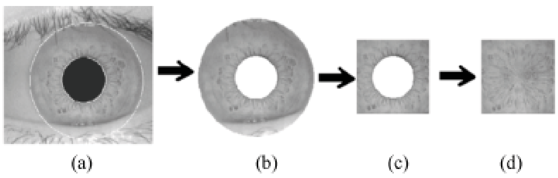


Fig. 6. Non-polar normalization image

The initial step is done by normalization of an iris image to an annular with fixed estimated. It appears in Fig. 6 (a), (b). Then choose the inscribed square of the external ring as the region of interest, this process shown in Fig. 6 (b) to (c). Finally, Fill the pupil area, Fig. 6 (d), using Bresenham's method. The use of non-polar coordinates can improve accuracy. Han et al. [24] used a contourlet feature and SVM classifier to recognize iris humans. It can be seen in **Error! Reference source not found.**.

TABLE I. RECOGNITION RATE COMPARISON OF CONVENTIONAL AND PROPOSED METHOD

Iris Number	Polar coordinates (%)	Non-polar coordinates (%)
27	74.07	100
54	70.37	100
81	70.37	97.53
108	66.67	96.30

E. Feature Extraction

Feature extraction in iris image categorized into three types, such as textural features (pattern and homogeneity), spectral features (color and gradient), and geometric features (edge, shape, and size). Finally, In this paper review, we will explain the feature extraction method, which was used by researchers.

- *Texture analysis*

The texture feature is the most widely used feature to recognize iris. Kekre et al. [2] use texture feature extraction using Haarlet Pyramid. They transformed image NxN toward Haar transformed. For the first level of Haarlet Pyramid, it produces approximation (hIA), horizontal (hIH), vertical (hIV), and diagonal (hID) components. Then, the approximate composition of the first level Haarlet is considered to be transformed with Haar T to get second level Haarlet. The result showed that higher level Haarlet is the best performance because it is giving coarse features while lower-level Haarlet is giving too beautiful texture so that it can be losing discriminant capability.

The use of feature extraction using Gray Level Co-occurrence Matrix (GLCM). This feature is widely used in texture analysis. GLCM based haralick feature was used by [13], [25], [26]. There are seven specific features used to recognize iris. It can be seen in Table II.

TABLE II. FEATURE EZTRACTION OF GLCM

Feature GLCM	Equation
Energy	$\sum_{i,j=0}^{N-1} p(i,j)^2$
Contrast	$\sum_{i,j=0}^{N-1} p(i,j)(i-j)^2$
Homogeneity	$\sum_{i,j=0}^{N-1} \frac{p(i,j)}{1+(i-j)^2}$
Variance	$\sum_{i,j=0}^{N-1} p(i,j)(i-\mu)^2$
Correlation	$\sum_{i,j=0}^{N-1} p(i,j)\frac{(i-\mu_x)(j-\mu_y)}{\sigma_x\sigma_y}$
Entropy	$-\sum_{i,j=0}^{N-1} p(i,j)log_2p(i,j)$
Dissimilarity	$\sum_{i,j=0}^{N-1} p(i,j)\|i-j\|$

A hybrid wavelet was done by [22]. Hybrid wavelet generated from two different orthogonal transforms [2]. Being a combination of two transforms, it combines excellent properties of both the component transforms. In that experiment, hybrid wavelet types I and II used for the multiresolution analysis of fingerprint and Iris ROI.

The most widely used texture feature extraction is a Gabor filter [14–17], [20]. The spatial and frequency domain are two gaussian shapes in the Gabor filter. So, the Gabor filter is a linear filter used for texture analysis. For this reason, they are steady in terms of several transformations, including translation, rotation, and scaling. Studied done by [17], they used Gabor and Morlet 2D wavelet to recognize iris humans. Besides that, mean and covariance are also computed to classify iris. The equation of 2D Gabor filter can be shown in (4) and (5):

$$G_c[i,j] = Be - \frac{(i^2+j^2)}{2\sigma^2} cos(2\pi f(i\, cos\theta + j \sin\theta)) \quad (4)$$

$$G_s[i,j] = Ce - \frac{(i^2+j^2)}{2\sigma^2} cos(2\pi f(i\, cos\theta + j \sin\theta)) \quad (5)$$

Another researcher used the Morlet wavelet transform to extract the eye image. It was done by [10]. The main goal of this method is to reduce the complexity of the iris recognition method because it carries an image to one-dimension through the Morlet wavelet transform. The iris image transformed into binary code, and this code is based on the imaginary coefficient of the wavelet transform. After getting the iris code, the next step is to bring the code into the classification process to give the recognition result

- *Texture and shape analysis*

A study done by [16], they use to shape and texture feature extraction for iris recognition. For local shape features, they used a Histogram of Oriented Gradient (HOG) to calculate the occurrences of gradient orientation in localized portions of an image. For texture feature extraction, they compare Gabor, GLCM, and Discrete Cosine Transform (DCT). Each segmented iris divided into four blocks to get the local texture feature because it can easily recognize than global features. The same studied done by [19]. They used DCT and Discrete Wavelet Transform (DWT) for iris recognition. Besides that, they used standard deviation features as a comparison to both of them.

F. Matching Process

The next step of feature extraction is identification and classification. The purpose of this process is to compare iris data that has extracted with the iris database. There are many kinds of methods to match two data using Euclidean distance [13], [14], [16], [22] and Hamming distance [8], [9], [11], [15], [17], [20], [21], [23]. Other methods used for this process were classification, such as using Support Vector Machine [13], [24], [25]; Probability Neural Network [18], and Convolutional Neural Network [12].

Euclidean distance in an image determined from the focal point of the source cells to the focal point of each surrounding cell, and the exact distance is determined to each cell in the distance function. The Euclidean distance formula between the two images is in (6).

$$d_E^2(x,y) = \sum_{i,j=1}^{MN} g_{i,j}(x^i - y^i)(x^j - y^j)$$
$$= (x-y)^T G(x-y) \quad (6)$$

where the symmetric matrix G = $(g_{ij})_{, MNxMN}$ will be referred to as the metric matrix.

Hamming distance in an image is based on logical exclusive-or (XOR) function is used because it ensures excellent performances in terms of speed and accuracy. The distance is computed as the number of bits whose value is 1 in the XOR result of the two given binary signatures. It can be seen **Error! Reference source not found.** in for the truth table of XOR.

TABLE III. THE TRUTH TABLE OF XOR

s_r[n]	s_i[n]	d (s_r[n], s_i[n])	Similarity
0	0	0	Similar
0	1	1	Not similar
1	0	1	Not similar
1	1	0	similar

IV. RESULT AND DISCUSSION

The proposed method for every researcher has briefly described in feature extraction. The result can be seen in **Error! Reference source not found.**.

TABLE IV. THE RESULT OF FEATURE EXTRACTION FOR EACH GROUP

Group	Database	Performance
Kekre et al. [2]	Palacky University (384 images)	GAR 64.58%, FAR 35.41%
Aala et al. [16]	UBIRIS v.1	ACC 96 % using GLCM
Hariprasath et al. [17]	UBIRIS v.1 (109 images)	Gabor (FAR 0.01, FRR 0.2), Morlet (FAR 0.2, FRR 0.2)
Min Han et al. [24]	National Laboratory of Pattern Recognition (5x108 images)	ACC 96.3-100 %
Meenakshi et al. [18]	UBIRIS v.1	CCR 97%
Vinayak et al. [22]	UPOL	81.5% using hybrid wavelet
Zhonghua Lin et al. [10]	CASIA	CRR = 99.64%, FAR = 0.301%, FRR = 0.4115%
Ameya et al. [19]	UBIRIS v.2	ACC 98% using DWT
Bhagyashree et al. [20]	UTIRIS V1 (15 Subject Images)	ACC 95%
Basma et al. [14]	CASIA database (2567 Images)	The best EER is up to 0.24% for a threshold of 0.493 with FAR = 0.06% at GAR = 99.5%
Onkar et al. [21]	MMU (450 Images), UTIRIS (792 Images) and IITD databases (2240 Images)	MMU = ACC 96.44%, UTIRIS = ACC 96.21%, IITD = ACC 97.14%
Thuong et al. [12]	CASIA Database (450 Images)	ACC 96.67%
Chandrashekar et al. [13]	CASIA database	ACC 95%
Rohini et al. [25]	Independent Measurement (30 Images)	ACC 93.75%
Basma et al. [11]	CASIA Database (2655 Images)	ACC 87%
Kalamullah et al. [15]	CASIA Iris V1 (108 Images	ACC 85.68%

Choosing the right database can produce proper iris recognition. From several papers that have been reviewed, each database has advantages and limitations. Usually, a good database on iris recognition is influenced by the number of images and how to capture an image. A study of iris recognition which has several images than the others. The study will produce a better contribution because of variations in the image, but it can increase the cost and complexity of an algorithm. The second factor is image acquisition. A good database is a detailed database in taking pictures of iris parts such as the right eye iris, left eye iris, eyelash, eyelid. Capturing an image is also done several times in each participant to make it more accurate. Based on **Error! Reference source not found.**, the UBIRIS database is widely used in iris recognition research. There are still a few researchers who use the IITD database that has a complete picture than the others. They have an iris image, eyelid, and eyelash image on each participant.

In the pre-processing step, there are four types of noise (eyelids, eyelashes, pupils, and reflection), which must be considered for iris recognition [27]. In this iris recognition research, we are not only focused on how to produce good iris localization using various methods but also pay attention to the noise that appears. So, it can increase the accuracy of iris recognition.

In this paper review, we can find a better method in segmentation and normalization methods. The segmentation method with Geodesic Active Contour (GAC) can obtain minimum Equal Error Rate (EER) 3.1% for the right eyes and 2.48% for left eyes. This percentage is lower than Zonghua, with the value of EER 0.35%. Both of them using database CASIA. One of the advantages of using GAC is their ability to handle "splitting and merging" boundaries. This is especially important in the case of iris segmentation since the radial fibers may be thick in some portions of the iris. The crypts present in the ciliary region may be unusually dark, leading to raised edges in the stopping function. GAC can split at such local minima and merge again. So, it can effectively deal with the problems of local minima, thereby ensuring that the final contour corresponds to the real iris boundary (see Fig. 4).

Commonly, the normalization method in iris recognition using Daughman's Rubber Sheet Model. This model will transform each point of iris inside to pair of polar coordinates (r, θ). It can make an easy analysis for the next step because one human with others has different data irises. Besides that, the iris and pupil are non-concentric. Therefore, this conventional method has a limitation. The polar coordinate model can solve interpolation and decimation problem. So, a novel normalization process that was used by Han et al. [24] generate a non-polar coordinate model. In their experiment, the use of this model can improve accuracy until 25-30% using texture and directional features. It can be concluded that a non-polar coordinate model can solve the problem obtained by Rubber Sheet Model.

For the feature extraction process, there is always a different method from one scientist to another. All of them have their own goals to recognize human iris. The differences between one of them are what method that was used to improve the accuracy and choosing a database. In this paper, we can see that every scientist has excellence and limitation in recognizing iris. However, based on the explanation in sub-feature extraction. We can conclude that the texture analysis feature is the most feature used by scientists. This feature can make it easy to recognize the iris because the texture of iris from one human to another is unique. One example is done by [16], this study used texture and shape feature analysis for iris analysis. They use HOC as shape feature and Gabor, GLCM, DCT as texture features.

Moreover, in order to know the performance from every feature, Aala et al. [16] compared an accuracy learned by using Logistic Model Tree (LMT) with four different combination features (HOG, Gabor + DCT, GLCM, Gabor + DCT + GLCM, and combined all features). The result showed that GLCM has the highest accuracy of 96%. The use of HOG obtained the lowest accuracy of 20%, it was reported as the worst accuracy. From this study, we concluded that texture feature extraction is the most optimal feature which explored for iris recognition.

Another study was done by [10]. They tried to increase the performance of iris recognition, which has done by Daughman. It is because Daughman's algorithm was known as the best algorithm at that time. However, the result showed that the algorithm has a constraint, this algorithm needs to process the two-dimensional information of the texture and causing the increase of feature extraction time. So, complexity of computation is a very high and not effective method. Another study was done by Boles and Boashas [28]. They proposed zero-crossing detection of the wavelet transform. This method is not suitable in small samples, and the recognition rate is lower. Furthermore, Z. Lin [10] used a Morlet wavelet transform, which made one-dimension information to the iris image in a sufficient area. So, it can reduce the complexity of computation.

Besides the feature extraction process, the time efficiency of the matching process is also an essential part of the iris recognition study. It can affect the performance of the recognition process. The faster and the precise an algorithm needed in iris recognition. So, the research can be said to achieve a good result. We can see the comparing result of the matching process from some researchers. From **Error! Reference source not found.**, we can conclude that the performance of Onkar et al. [21] is lower than the others. The used three different iris databases, and the result of the matching process is high-speed and efficient with accuracies in every database, such as MMU = ACC 96.44%, UTIRIS = ACC 96.21%, and IITD = ACC 97.14%.

TABLE V. THE COMPARISON PERFORMANCE FOR MATCHING PROCESS

Method	Matching (s)
Daughman et al	4.3
Boles et al. [28]	11
Aalaa et al. [16]	65
Bhagyashree et al. [20]	0.467
Onkar et al. [21]	0.34 (MMU); 0.64 (IITD); 0.68 (UTIRIS)
Thuong et al. [12]	0.1-0.9
Basma et al. [14]	15.82

V. CONCLUSION

This paper gives a review of different existing strategies proposed by various researchers for iris recognition. All performances method depending on the different algorithms used. However, from this study, we conclude that a good study of iris recognition is not only based on the choosing feature extraction method but also with considering the time computation needed in the recognition process. The proposed algorithm can be said to be good if it has a low time computation and can be used in general not only for one database but also for several databases with a good performance. The result is certainly based on several studies included in our analysis. More kinds of literature will provide better analysis and knowledge gain in developing a review study. The drawback of such a study is that the research environment of each study sometimes was not comparable.

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