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Flexible Off-line Arabic Handwritten OCR Based on Web Services

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Abstract. Despite the large number of approaches and techniques proposed to solve the Arabic handwriting recognition problems, the corresponding results remain weak. Indeed, intensive experiments revealed that such approaches and techniques are unable to deal properly especially with large quantity of handwritten Arabic documents. The complex morphology of the Arabic writing is mainly behind this weakness.

A deep study of some of these existing proposed approaches and techniques revealed fortunately their complementarity. Such a complementarity can be exploited on making them collaborating together in a flexible manner. This flexible collaboration can improve substantially the recognition rate and may be leading consequently to building powerful Arabic handwriting systems.

Web services seem to be an adequate technology which can make possible the flexible collaboration of several approaches and techniques to solve certain problems.

Consequently, we present first in this paper a comprehensive review of Arabic handwriting recognition commonly known as Arabic Optical Character Recognition (AOCR) approaches and techniques. Then, we present our idea which consists to build AOCR based on the flexible collaboration of two or more complementary approaches and techniques by using web service technology.

Keywords: Optical character recognition (OCR), Arabic characters, Web Services, Web Services composition, Complementary approaches, Flexible collaboration.

1. Introduction

Arabic documents recognition is a very important subject for both Arabs and non-Arabs communities. Indeed, Arabs need these tools for transforming all printed and handwritten materials into electronic media, while non-Arabs look at it as intermediate step towards fully transliterating Arabic text particularly the very large and diversified quantity of old Arabic manuscripts dispersed around the world which includes very useful knowledge maybe not yet discovered. Human writing can be hard to understand or to recognize by a mechanical and automated system. In order to simplify the process, it is needed for the specific software to work using worldwide web service databases, where every character is associated to a typed character, no matter the handwriting style of the user. Off-line recognition of handwriting can be a very difficult task, since people have different styles of writing using their hands rather than typing the text using a physical keyboard.

Optical character recognition (OCR) aims at translating an input binary image of text into an editable text which can be manipulated by a text editor[1].

In this work we will show that the flexible collaboration of some complementary approaches related to Arabic OCR can lead to the implementation of powerful systems whatever the target architecture. Such collaboration can be achieved easily through web services which present several advantages especially the possibility of combining (composing) in a flexible manner such approaches and techniques.

Indeed, with the evolving of the internet, researchers attempted to find a technology that make possible providing to users different kinds of services (applications) on the web. This technology is called web services where each of which is intended to solve a specific problem. This technology is also based on XML standards. The most attractive advantage in such a technology is the composition mechanism which makes possible the flexible collaboration of some customized web services in order to solve some complex problem[2], [3].

The rest of this paper is organized as follows; in the second part, we present a literature review related to the studied topic. The third part of this paper details the proposed system and the conducted experiments. A conclusion and some future works are presented at the end of this paper.

2. Literature review

2.1 Handwritten Optical Character Recognition

Arabic handwriting OCR (AHOCR) is very important since a large amount of Arabic documents are still waiting for their computerization due to the richness of their contents. The manual computerization of these documents will be very expensive in cost and time. A lot of research has been done in this area, but researchers still continue to optimize the recognition rate which is yet low in AHOCR compared with other languages such as Latin. We will review and summarize next some of existing works in AHOCR. Actually, the existing works can be classified into two categories; Holistic and Analytic strategies. In the holistic strategies, words or sub-words are recognized without a prior segmentation. But in the analytic strategies, words and sub-words are segmented firstly into characters or features. It is well known that most of the holistic strategies cannot deal with large vocabularies since they deal with words and sub-words. However, analytic strategies are supposed to be able to deal with large and open vocabularies since they deal with characters or parts of character.

In [4], Farah *et al* presented an new Arabic OCR system that used three classifiers (ANN, KNN and Fuzzy KNN) and structural features. The classification step performed in parallel combination schema. The result of classification stage normalized first, and combination schema is performed. At last the decision on Specified words can be done. This system tested in 48 words achieved a 96% recognition rate.

In[5], Bennamoun and Bergmann proposed an Arabic OCR system which avoids the classic segmentation by performing this task during the recognition process. The proposed system is depicted in Figure 1[6]. According to the authors, the proposed system has achieved 90% recognition rate.

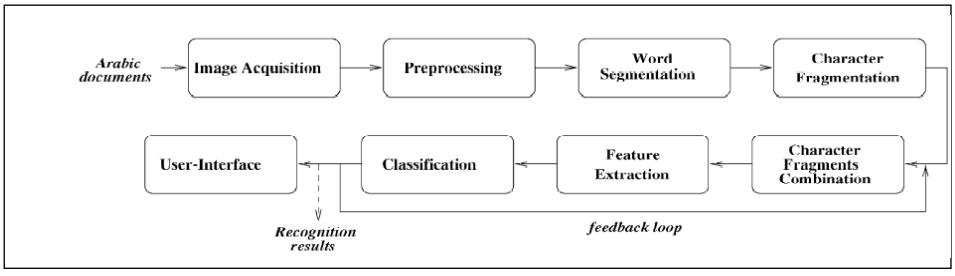

Fig. 1. The general architecture of the system proposed by Bennamoun.

In[7], Dehghan, *et al.,* presented a new system to recognize isolated handwritten character based on HMM classifier. This system consists of two phases: training and recognition phases as illustrated in (Fig. 2). This system tested on 198 names of cities and achieved a 65% recognition rate.

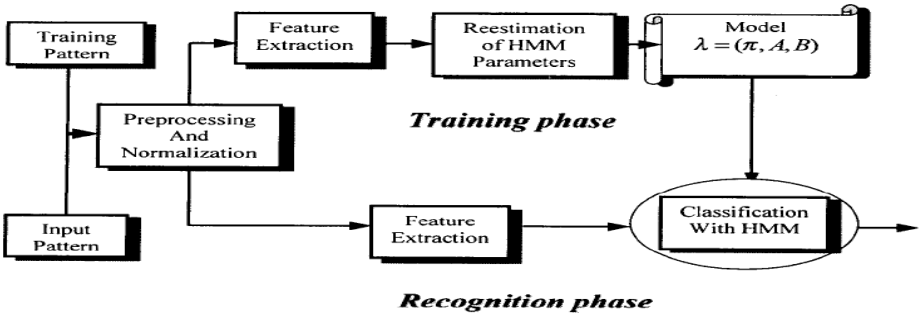

Fig. 2. Overall structure of the proposed handwritten character recognition system.

In[8], Khorsheed presented an new Arabic OCR system based on HMM and structural features extracted from word skeletons. The proposed system achieved 89% recognition rate.

In[9], Pechwitz and margner also presented a new Arabic OCR system based on HMM classifier which considers some specific features extracted from some specific columns of pixels. The experiments were conducted on the IFN/ENIT database and 89% recognition rate was reported.

In[10], Menasri, *et al.,* proposed a new off-line handwritten Arabic words recognition system that used hybrid recognizer HMM/NN. In this hybrid system HMM model represent each letter-body class and NN computes the observations probability distribution. The authors tested their system using IFN/ENIT which has a vocabulary of 937 city names and achieved a 87% recognition rate.

In[11], the authors propose a planar modeling approach based on HMM. The aim of this approach is to decomposition the writing into a limited set of elementary entities. Therefor the writing was divided into five logical horizontal bands corresponding to descanters, ascenders, median zone, upper diacritics and lower diacritics. Figure 3 shows how the segmentation process allows them to reduce the complexity of the treated shapes.

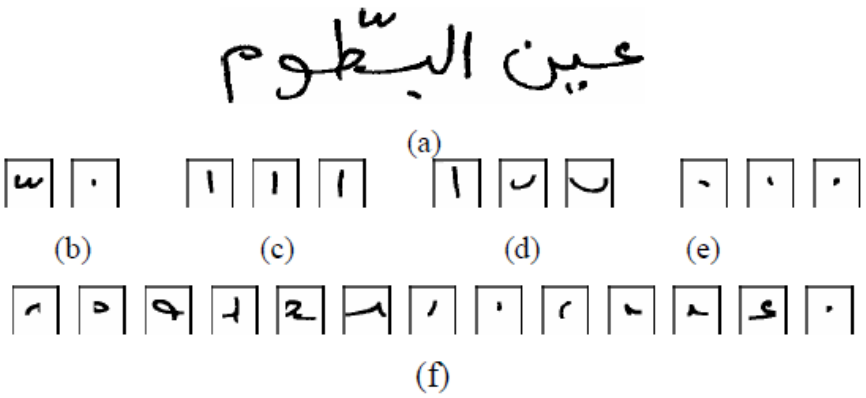

Fig. 3. (a) Original image of city name "عين البطوم" and the extracted grapheme belonging to, (b) upper diacritics, (c) ascenders, (d) descanters, (e) lower diacritics and (f) median zone.

The authors tested their system using IFN/ENIT and achieved a 86.1% recognition rate.

In[12], the author proposed a new Arabic optical character recognition (*AOCR*) system based on a neural network classifier and depicted in Figure 4. This system achieved 87% recognition rate.

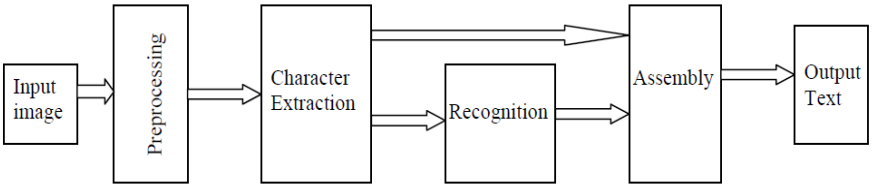

Fig. 4. System architecture.

In[13], the authors proposed an OCR system based on single-state HMM. The authors tested their system using IFN/ENIT and achieved a 80.95 % recognition rate.

In[14], the authors proposed an off-line Arabic handwriting recognition system. The processing is achieved in three main stages. Firstly, the image is skeletonized to one pixel thin. Secondly, transfer each diagonally connected foreground pixel to the closest horizontal or vertical line. Finally, these orthogonal lines are coded as vectors of unique integer numbers; each vector represents one letter of the word.

The system has been tested on the IFN/ENIT database to evaluate the proposed techniques and achieved a 97% recognition rate. The proposed algorithms are described according to the offline handwriting recognition process described in (Fig. 5).

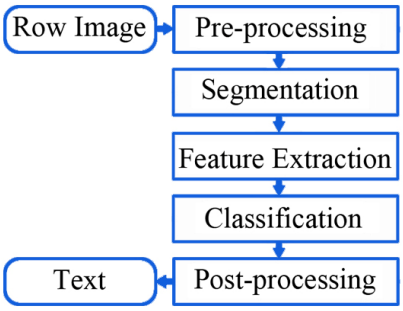

Fig. 5. Stages of character recognition process.

In[15], Abdurazzag and Salem proposed an Arabic OCR system that consists of three stages, preprocessing, feature extraction and recognizer (Fig. 6). This research proposed a new construction technique of OCR similar to the one using wavelet compression. This system has achieved an accuracy (97.7% for some litters at average 80%).

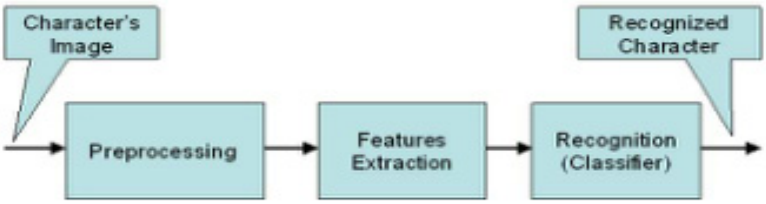

Fig. 6. The typical structure of OCR system.

In[16], Almuallim and Yamaguchi proposed a system organized into four stages, preprocessing, segmentation, feature extraction and classifier. The main idea of the proposed system is based on some geometrical and topological properties of some words. This proposed system was tested on 400 words and showed an accuracy of 91%.

Table 1, classifies the previous works into the two presented strategies. And Table 2 summarizes the most important features of these presented strategies.

Table 1.1. classification of the presented works.

Holistic strategy	Analytic Strategy
(Farah, *et al.,* 2004)[4]	(Bennamoun, *et al.,* 2000)[5]
(Khorsheed, 2003)[8]	(Dehghan, *et al.,* 2001)[7]
(Pechwitz, *et al.,* 2003)[9]	(Hani, 2006)[12]
(Menasri, *et al.,* 2007)[10]	(Abdurrazzag, *et al.,* 2007)[15]
(Touj, *et al.,* 2005)[11]	
(Dreuw, *et al.,* 2008)[13]	
(Jafaar, *et al.,* 2013)[14]	
(Almuallim, *et al.,* 1987)[16]	

Table 2. Important Features of the presented strategies.

Author	Feature	Classifier	Size of word	Rec. Rate (%)
Farah, *et al.,*[4]	Structural	ANN, KNN & Fuzzy KNN	48 words (100 writers)	96
Bennamoun and Bergmann[5]	chain code	Recognition based-segmentation	20 characters	90
Dehghan, *et al.*[7]	Histograms of freeman chain code	HMM	17,000 images of 198 names	65
Khorsheed [8]	Structural	HMM	405 characters	87
Pechwitz and margner [9]	Columns of pixels in the blurred thinned image	HMM	26,459 images of 946 city names	89
Menasri *et al.,* [10]	Graphemes	HMM/NN	training: a-e, test: f	87
Touj *et al.,* [11]	Directional values, connection of graphemes	Planar HMMs	training: a-d, test: e	86.1
Hani Khasawneh [12]	silent features	Neural Network	5464	87
Dreuw *et al.,* [13]	Image slices and their spatial derivatives	HMM	training: a-d, test: e	80.95
Jafaar Alabodi and Xue Li [14]	junction-points, end points, and connectivity between the components for the further processing needs	Unknown	2000 words	93.3
Abdurazzag and Salem [15]	Structural	Wavelet Compression	1968 letters	80
Almuallim and Yamaguchi [16]	geometric and topological	String matching	400 words	91

In the next section we will give an overview on web services composition since we will use this technique to combine (integrate) OCR complementary approaches.

2.2 web services

To maintain a good management strategy in a given organization, one needs various software systems in order to communicate. Web services offer methods of communication between two devices over a network, being described as "a software system designed to support interoperable machine-to-machine interaction over a network". Web services are evolving continuously because of the different and increasing needs of organizations and companies[17], [18]. Today, it is possible for organizations to communicate and share together a wide range of knowledge, applications… web services and more generally service oriented architecture (SOA) constitute the main tool of such possibilities. Moreover, web services provide the possibility to work in collaboration in order to achieve some complex tasks related to business processes. This collaboration between services is achieved through Web service composition approaches and techniques[19].

In[20], the authors proposed an extended SOA model for service composition and service dependency. The authors established a dependency demands aware service-oriented architecture (DSOA) to specify dependency aware service interactions, *i.e.*, service publication, discovery, composition and binding. The authors claim that traditional Service Oriented Computing (SOC) focuses on service composition for application development.

In[21], the authors proposed a new service composition mechanism based on peer-to-peer (*P2P*) network. An extended state machine model is shown to identify network model from a service. The model describes a service and its execution patterns. Three execution patterns (AND, OR and Sequential patterns) are basic service composition constructs of the model. The model serves as a basis for service composition algorithm. Service composition algorithm describes the process of service composition in detail. A graphic model based on one of the execution patterns turns out to be the input of the algorithm.

3. The proposed system

In this research we propose a new idea based on a flexible collaboration of some selected strong complementary approaches and techniques whatever the target architecture. We mean by flexible, the possibility to customize the recognition rate by adding or reducing the number of approaches and technique that will collaborate together empirically. This flexibility can be achieved by implementing our selected Arabic handwritten OCR (AHOCR) as web services since this technology provides the adequate tools for this purpose.

It is well known that web services can be executed on different architectures and platforms according to the agreement between their providers and users. But the corresponding execution is achieved always on the provider side that is the responsible of the user data security. In this paper we are concerned especially by the execution of such services on local and small machines like laptops (user side) in order to show how one could use this technology locally without disclosing his data. It means that we have supposed that the provider can allow the execution of his own services on the client or user side. This is one of the expectations of web services users.

In this research we focused mainly on the cooperation of the ***k*-Nearest Neighbors** (KNN) and **Support Vector Machine** (SVM) techniques because of their good performance and complementarity which are well explained in[23] and[28]. Figure (7) illustrates the experimented system.

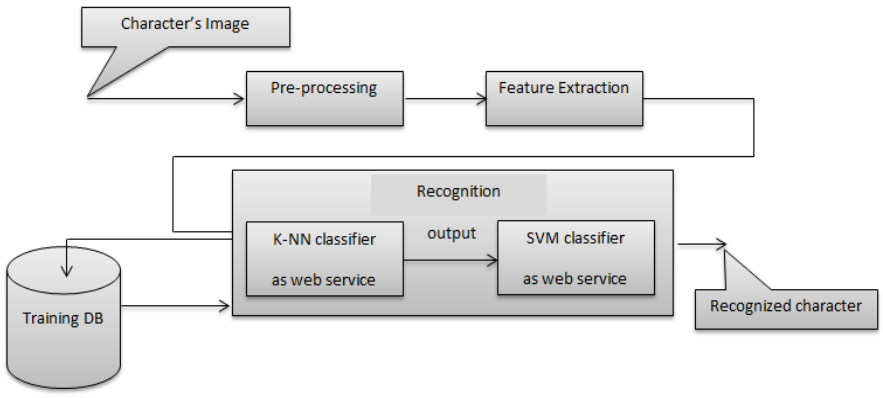

Fig. 7. The structure of the proposed Arabic OCR system.

SVM as a decision classifier to exceed the limits of **K-NN** as illustrated in (Fig. 8).

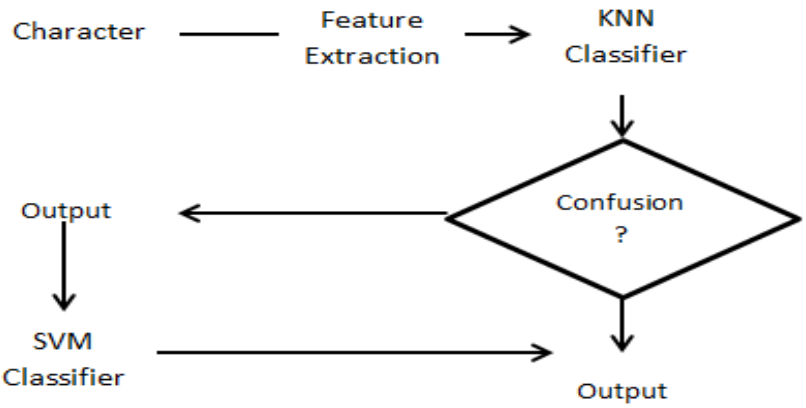

Fig. 8. K-NN /SVM mechanism.

3.1 k-Nearest Neighbors (KNN)

KNN is one of the most important non-parameter algorithms for pattern recognition[22]. It is used to classify a character by looking for the k nearest neighbor among the training data sets according to specific criteria[23] and consider the closest ones.

As example, if we need to classify E which is a new character, we have to follow up the following steps:

- Calculate all distances between E and all classes (28 Arabic characters in their different shapes according to their position within a given word or sub-words) in the training set: $C_1, C_2,\ldots,C_j$.
- Select K closest classes to E; where $1<K \leq 4$ (4 represent the maximum shapes similarity in Arabic characters).
- E will be assigned to the most common class among its K-nearest neighbors.

The distance between E = (E1, E2,…,Ej) and nearest neighbor C, defined as illustrated by equation (1):

$$D(E,C) = \sqrt{\sum_{i=1}^{n}(E_i - C_i)^2} \quad (1)$$

3.2 Support Vector Machine (SVM)

SVM is a new type of pattern classifier. This classification technique is based on a novel statistical learning approach[24]. SVM have been applied in handwritten character and digits recognition also can be applied in different application like face detection, face recognition object detection, object recognition[23]. SVM used to reduce the risk[24].

Several conducted experiments revealed that K-NN algorithm is one of the best leading to good accuracy for different data sets[25, 26, 27].

K-NN represents a very intersecting classifier for Arabic handwriting recognition because of its great adaptability and versatility in handwriting sequential signals[28].

In this work we have proceeded to the collaboration of these two techniques KNN-SVM by implementing them as web services in an attempt to improve the accuracy of character recognition process. The idea behind this selection is that SVM should refine the results found by KNN.

Table 3 explains the advantages and disadvantages of these two experimented techniques.

Table 3. K-NN vs SVM.

Technique	Advantages	Disadvantages
k Nearest Neighbor (k-NN)	1. Training is very fast 2. Simple and easy to learn 3. Robust to noisy training data 4.Effective if training data is large	1. Biased by value of k 2.Computation Complexity 3.Memory limitation 4. Being a supervised learning lazy algorithm *i.e.* runs slowly 5. Easily fooled by irrelevant Attributes
Support vector machines (SVM)	1. Effective in high dimensional spaces. 2. Still effective in cases where number of dimensions is greater than the number of samples. 3. Uses a subset of training points in the decision function (called support vectors), so it is also memory efficient. 4. Versatile: different *Kernel functions* can be specified for the decision function. Common kernels are provided, but it is also possible to specify custom kernels.	1. If the number of features is much greater than the number of samples, the method is likely to give poor performances . 2. SVMs do not directly provide probability estimates, these are calculated using an expensive five-fold cross-validation (see Scores and probabilities, below).

3.3 Results and discussion

3.3.1 The experimental study

To evaluate our system**,** we made various experiments to measure its efficiency. These experiments were carried out on the IFN/ENIT database[30]. As a features extraction technique, we have used the Wavelet transform[29].

For this purpose we evaluated, in the first hand the importance of the hybrid approach K-NN/SVM in the recognition rate and in the second hand the efficiency of using web services technology on the execution time of the proposed hybrid K-NN/SVM approach, The three web services was created, first for KNN method, second for SVM method, last for KNN and SVM together.

3.3.2 Datasets

Any recognition system needs a large database to train and test the system, one of the these databases is IFN/ENIT which containing 26459 handwritten Tunisian town/village names, 115585 PAWs and 212211 characters scanned at 300dpi and written by 411 different writers. We have used the entire normalized IFN-ENIT as dataset for training and learning[31].

3.3.3 Experimental environment

The tests were conducted on a local Intel(R) core™ i3-2377 M CPU@1.50 GHz having the following configuration: 4.0 GB of RAM running a Windows7 operating system. VB.NET, visual studio 10 were used to implement and built our OCR application.

3.3.4 Results and discussions

In this section the obtained results are presented. The 28 Arabic characters written with different scripts in different positions in the word representing all the classes used in our experiments. The recognition rate using K-NN and K-NN/SVM is presented respectively in the following Table 4.

Table 4. K-NN and K-NN/SVM recognition rate (%).

Classes	K-NN Rate (%)	K-NN/SVM Rate (%)
ا	96.20	97.70
ب	95.00	96.51
ت	94.90	96.30
ث	95.40	96.20
ج	96.10	97.30
ح	96.30	97.50
خ	95.30	96.40
د	95.30	96.60
ذ	95.80	96.20
ر	95.40	96.30
ز	95.00	96.30
س	95.15	96.60
ش	95.20	96.25
ص	96.00	96.60
ض	95.92	97.00
ط	96.10	96.80
ظ	96.00	96.95
ع	95.80	96.65
غ	95.95	96.80
ف	96.00	96.80
ق	95.90	97.00
ك	95.80	96.90
ل	96.20	97.10
م	95.60	96.80
ن	95.90	97.00
ه	96.25	97.35
و	96.00	97.10
ي	95.75	96.80
Average (%)	95.70	96.80

Table 4 shows that the collaboration of K-NN and SVM classifiers leads to better results.

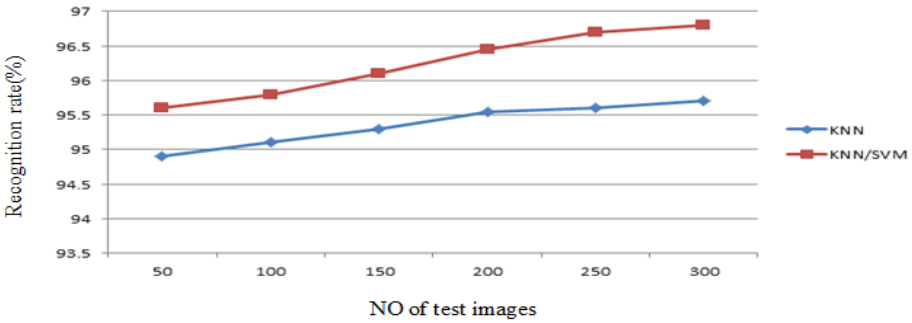

Fig. 9. K-NN and K-NN/SVM and their relationship to increase the number of test images.

The Figure 9 shows that the recognition rate of K-NN and K-NN/SVM has increased when the number of test images has increased.

The Figure 10 below presents the execution time using K-NN and K-NN/SVM with different number of web services.

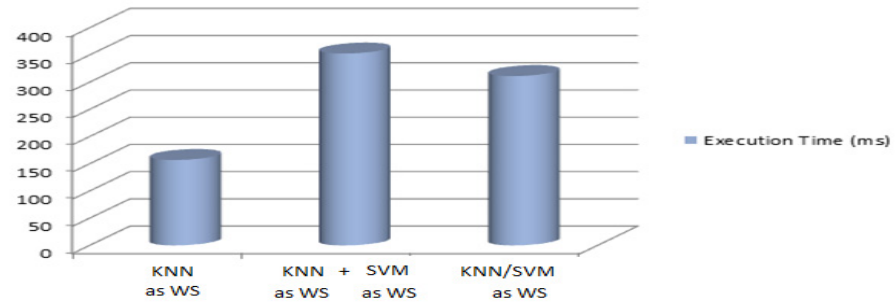

Fig. 10. Execution time using K-NN and K-NN/SVM with different number of web services.

The Figure 10 shows that the execution time of K-NN is less than the execution time of K-NN/SVM. It shows also that the execution time of K-NN/SVM built as one web service is better than the execution time of K-NN/SVM built as two separated web services. This means that if we would like to improve the response time of a set of web services collaborating together, we can merge some of them within the same web service whenever this is possible.

The Figure 11 below presents the comparison between K-NN and K-NN/SVM in terms of execution time and recognition rate.

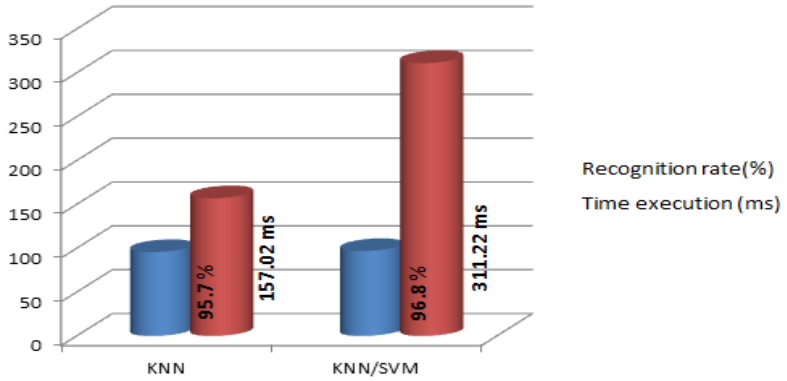

Fig. 11. comparison between K-NN and K-NN/SVM for the execution time and recognition rate.

The Figure 11 shows that the improvement of the recognition rate is unfortunately accompanied with an increasing of the execution time. This is expected since the collaboration of K-NN/SVM is achieved in a sequential manner (cascade).

According to the results that we got from the performed tests and experiments, we can say that:

- The hybrid K-NN/SVM classifiers improve the accuracy of Arabic OCR.
- There is a trade-offs between high recognition rate and cost (time), hybrid K-NN/SVM take more time and hence more cost.
- The implementation of K-NN/SVM on a single web service improves the execution time.
- The overall enhancement of recognition rate is about 1.00% compared with single classifier.
- The web service technology can be an appropriate way to make possible the flexible collaboration of several approaches and techniques that leads to a customized recognition rate.

4. Conclusion and Future Work

4.1 Conclusion

In this paper, we have introduced a novel idea based on web services leading to an easy collaboration of complementary approaches related to Arabic OCR. The collaboration of complementary approaches is very interesting since it can lead to a significant improvement of the accuracy of the future OCR systems. The implementation of KNN and SVM as web services and their collaboration constitutes a proof of the viability of our idea.

4.2 Future Work

As a future work, we intend conducting more experiments in order to find better complementary approaches that can improve substantially the recognition rate and can lead to build a powerful OCR system.

We intend also to find the optimal way to speed up the execution time of such a powerful OCR system in order to provide users soft and enough fast systems.

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التعرف المرن على الخط العربي استنادًا لخدمات الويب

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المستخلص. على الرغم من وجود عدد كبير من الأساليب والتقنيات المقترحة لحل مشاكل التعرف على الكتابة اليدوية العربية، لا تزال النتائج ضعيفة. حيث كشفت التجارب المكثفة أن هذه النهج والأساليب غير قادرة على التعامل بشكل صحيح خصوصًا مع كمية كبيرة من الوثائق العربية المكتوبة بخط اليد. والسبب الرئيس وراء هذا الضعف هو تعقيد مورفولوجية هذه الكتابة.

لحسن الحظ كشفت دراسة عميقة لبعض هذه الأساليب والتقنيات المقترحة عن تكاملها. حيث يمكن استغلال مثل هذا التكامل على جعلها تتعاون معًا بطريقة مرنة. هذا التعاون المرن يمكن أن يحسن بشكل كبير من معدل الاعتراف ويمكن أن يؤدي بالتالي إلى بناء أنظمة قوية للتعرف على الكتابة اليدوية العربية.

ويبدو أن خدمات الويب هي التكنولوجيا الملائمة التي يمكن أن تجعل من الممكن التعاون المرن بين عدة طرق وتقنيات متكاملة لحل مشاكل معينة.

ونتيجة لذلك، فإننا نقدم أولاً في هذه الورقة استعراضًا شاملاً للتعرف الضوئي على الكتابة اليدوية العربية. ثم نقدم فكرتنا التي تتكون من بناء نظام على أساس التعاون المرن بين اثنين أو أكثر لأساليب وتقنيات متكاملة باستخدام تكنولوجيا خدمة الإنترنت.