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Novel Algorithm for Baseline Detection of Offline Arabic Handwritten Text Recognition

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ABSTRACT

The baseline detection is one of the challenging tasks in the pre-processing stage of an online Arabic handwritten text recognition. The challenges include text skewness, touching letters or words, short words, sub-words, ligatures, isolated characters, small descenders, and diacritics. This paper presents a novel automated algorithm for baseline detection that is able to overcome the previously mentioned challenges. The proposed baseline algorithm mainly used a skeletonizing algorithm to estimate the baseline for each sub-word that appear in the image separately. The proposed algorithm had been tested using the benchmark handwritten Arabic database, i.e., IFN/ENIT database. The experimental results showed that it is able to reduce the average error between the actual baseline and the resulting baseline to 3.39 pixels for all sub-words and achieved an average of 3.6% in the ratio between the error pixels and the image height. In addition, the proposed algorithm shows that it is superior as compared to four others benchmarked baseline detection algorithms. It is anticipated that this algorithm will be able to be applied for many Arabic offline handwritten applications in the future.

1. Introduction

Computer vision encompass wide variety of application area such as image processing, pattern recognition, text recognition and many other areas [1]. The use of computer vision technology will help millions of people [2]. One of the other computer vision interesting fields is text recognition. High-accuracy text recognition is an essential challenge to computer scientists because it has been employed in many useful applications [3]. Basically, text recognition aims to convert the digital image of text to digital text [4]. This conversion leads to enhancing the readability of the digital text to be more useful for storing, editing, translating, reading, and various other applications by computer systems [5-8].

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Text recognition is one of the major challenging tasks in the domain of pattern recognition due to the characteristics of the writer sensitivity as well as complexity in writing handwritten shapes [9]. Text recognition has been employed in many different applications including official contracts and processing of bank cheque applications, postal mail sorting and many others [10]. Text recognition can be categorized into two major types; printed text image and handwritten text image [4]. A printed text image is the text which is typed by a computer or printing machine. The handwritten text is the text written by hand. Arabic handwritten text recognition is a very important and modern field in digital vision. The accuracy of the Arabic handwritten text recognition systems is still not sufficient to yield real life need [12]. In general, the development of automated handwritten text recognition algorithms is more complex than printed text recognition. This complexity in research and development in handwritten text recognition is due to the fact that most writers disregard the writing rules which leads to challenges in text recognition algorithm to automatically detect the word(s). Among the challenges are text skewedness, slanted, disproportioned characters, touching letters or words, short word, sub-words, ligatures, isolated characters, small descenders, and diacritics [13].

In another perspective, the handwritten text recognition system can be categorized either as online or offline. An online text recognition system is implemented when the text is fed to the system by typing it on a pressure-sensitive tablet; where both text typing and text recognition execute at the same time. On the contrary, the offline text recognition system is applied when an image or paper which includes the text is scanned and stored as a digital image into the system [14]. The online system has more detailed information about the text, like the sequential order of the typing and the immediate temporal information. Thus, it makes the process of an online handwritten text recognition system easier and straight forward to be developed as compared to its offline counterpart [12]. The writing process of each language has special characteristics. The text recognition complexity is affected by these characteristics. The Arabic language has a very complex writing characteristic. Therefore, Arabic language recognition is considered more complicated process comparing to the Chinese, Latin and many other languages [11]. One of the most important characteristics is cursive writing where cursive writing makes the letters are connected, which in turn makes letters recognition more difficult than the separated letters [15]. In addition, there are some other characteristics of Arabic text that makes the process of text recognition more challenging such as diacritics, points in characters, Arabic letters has different shapes based on its position in the word and the Arabic word may also include several sub-words [12]. These characteristics make the Arabic handwritten text recognition difficult and poses challenges to the Arabic text recognition research community up to today [16].

In general, the preprocessing stage is the most vital stage of the handwritten text recognition process because its results will strongly affect the following stage in the text recognition process [11]. The preprocessing stage includes several tasks. One of these tasks is baseline detection which is one of the most critical tasks in text preprocessing stage. This process is critical because its results will affect the following tasks such as skew and slant correction, segmentation and features extraction processes [17-21]. The baseline is a pseudo horizontal line which connects the ascender strokes and descender strokes. Baseline detection is useful to detect the number of lines in the document, normalized the characters in the text and other related preprocessing task before actual text recognition took place [20].

The first Arabic text baseline detection was carried out by Parhami and Taraghi [22]. This work was based on the horizontal projection diagram to recognize Persian text. This method achieved a very good results in the printed Arabic text, but it fails in the Arabic handwritten text. Since then, there are many other methods that have been presented for Arabic text baseline detection. These methods can be categorized into four approaches; horizontal projection, word skeleton, word contour representation, and Principal Components Analysis (PCA) [23]. Naz *et al*., [24] described that there are other methods for baseline detection; Voronoi diagram, Hough transform and entropy.

The rest of this paper is organized as follows. Section 2 describes a brief review of the baseline detection algorithm. Section 3 presents the research methodology used in this paper. Section 4 describes the experimental setup and section 5 presents the experimental results followed by the discussion. Finally, the conclusion and proposed future works is presented in Section 6.

2. Literature Review

As previously mentioned, the horizontal projection diagram is the principal of the first baseline detection method [25]. It was mainly developed to recognize printed Persian characters. This method is widely used because it is easy to apply. It succeeded just in the printed text but it failed with the Arabic handwritten text because of the skew, descenders and diacritics [23]. Olivier *et al.,* [25] presented a baseline detection method. This method is done in two stages. The first stage is based on the locations of the loops that are close to the baseline in the Arabic text. The second stage is based on the decisive segmentation point. In general, this method achieves aa good accuracy in the Arabic handwritten text compared to the horizontal projection method. However, it failed with the skew and it require long computational time. Pechwitz and Margner [26] proposed a method based on the skeleton of the Arabic handwritten text in the first stage. From the obtained skeleton, a number of candidate points for the baseline were extracted. It follows by the removal of all the unhelpful strokes like diacritics, points isolated letters and descenders. After that, the first baseline estimation is made based on the remaining candidate points. The second baseline estimation is made based on the regression technique. The accuracy of this method is relatively low, and it faces problems with the short words, skewed words, and separated characters. The accuracy of this method however is better than the horizontal projection in the handwritten Arabic text.

Burrow [27] employed the principal component analysis (PCA) and the horizontal projection diagrams method to make the baseline detection. PCA was used to set the image baseline direction based on pixels distribution of foreground and background. The accuracy of this method was negatively affected by the diacritics. Also, it is affected by the horizontal projection disadvantage. El-Hajj *et al*., [28] introduced a method based on the horizontal projection to detect two baselines (upper and lower baseline). This method faces the same problem which facing the horizontal projection. Farooq *et al*., [29] introduced a method for baseline detection based on the word contour representation. Their method has been evaluated using the benchmark Arabic handwritten database IFN/ENIT. This method achieves better accuracy than the method proposed by Pechwitz and Margner [26]. The authors mentioned that the baseline ground-truth which had been set by IFN/ENIT is not accurate. Therefore, the authors prefer the manual calculation of the result. By using this method, it shows that it does not need to correct the skew in the text. On the other hand, this method faces problem with regression, large diacritics, and noise. It is noteworthy that the word contour representation is a very good method for word segmentation and for sub-word extraction because the main principle of this method is based on boundary tracking. Al-Rashaidehi [30] used the horizontal projection and the iteration of the angles to detect baseline in Arabic handwritten text. In order to enhance the performance of the horizontal projection, the iteration of the angles had been used in this method. So, this method achieved accuracy more than the horizontal projection, but the accuracy of this method is still considered low with the handwritten Arabic text. Ziaratban and Faez [31] suggested a new method for baseline detection by utilizing the horizontal segmentation of the image and five templates. This method had the ability to handle the Parsi text and the Arabic text at the sub-word level. According to Al-Khateeb *et al.,* [32], the Arabic baseline location is in the lower half of the text image. Thus, the horizontal projection diagrams were applied in the region located under the middle of the text. This method significantly reduced the run time. Based on the text skeleton, Boubaker *et al*., [33] presented a baseline detection method to solve the problem of the Arabic short word. Nagabhushan and Alaei [34] presented a method using curvedness and piece-wise to create binary blocks. The detected curve was implemented to detect several candidate points before detecting the baseline. Boukerma and Farah [35] presented an algorithm for Arabic baseline detection in sub-word level based on the skeleton of the text and the horizontal segmentation. This method was accomplished in two stages; extract of feature points and the sub-word contour. The proposed method achieved relatively high accuracy, although it faced problems with big diacritics, overlaps, and small descenders. Abu-Ain *et al*., [36] introduced an algorithm based on the horizontal projection and the skeleton of Arabic sub-words, but this method failed with the short word [36]. Baz and Baz [21] presented a method via multiple-angle histogram. This method achieved high accuracy. However, the accuracy of this method is still affected by problems like skew, unbalanced size of the characters, and short words. Al-Shatnawi [37] used voronoi diagrams to estimate the straight and curved Arabic baseline. Depending on the clustering of interest points, Fawzi *et al*., [20] presented a method that operated by training and testing Arabic text database. The best results were obtained by four training iterations compared with its computational time. This method is affected by the width of the handwritten text strokes. AL-Khatatneh *et al*., [19] proposed an approach based on the baseline candidate region, the branching, and crossing points. The method of Boukharouba [38] used the lower edge of the contour and randomized Hough Transform. This method failed in IFN/ENIT database because of the non-uniform skew with multiple sub-words, multiple sub-words with different baselines, and lower edges of the sub-words not straight.

Based on the presented methods in these previous studies, several challenges were observed for the handwritten Arabic word baseline detection. These challenges are noise, thinning, skew, sub-word, ligatures, overlapping, freewriting, isolated characters, short word, touching letters or words, different characteristics of Arabic script, points, and diacritics. In general, the accuracy of the baseline detection is affected by these challenges. The majority of these challenges were considered in this new proposed approach in this paper and a significant enhancement was obtained to improve the Arabic text baseline detection.

3. The Proposed Method

In this paper, a new method for baseline detection for the Arabic handwritten text is introduced. This proposed method works by detecting a separated baseline for each sub-word. The sub-word is extracted based on the vertical segmentation of the image. The vertical segmentation uses a vertical projection diagram. It is mainly based on skeleton of the Arabic word and candidate points. Diacritic is an important characteristic in the Arabic language where it is a sign written above or below the letter to indicate the right sound of the letter. Some methods removed the diacritics to ease the baseline detection. This diacritics removal is based on the size of the strokes. This removal leads to small letters deletion because the size of the diacritic is sometimes bigger than the letter size. Based on the Arabic text characteristics, we noted that the big size diacritics are written above the letters; exactly in the upper horizontal quarter of the text image. In this proposed method, the text image has been divided into four equal horizontal regions. The upper region includes the big size diacritics and it does not include the baseline. Therefore, the upper region has been excepted from the process of baseline search. This step achieves two advantages. The first advantage is to get rid of big size diacritics problem, without deleting any letters. The second advantage is, it will reduce the run time of the algorithm.

The newly proposed baseline detection algorithm are as follows:

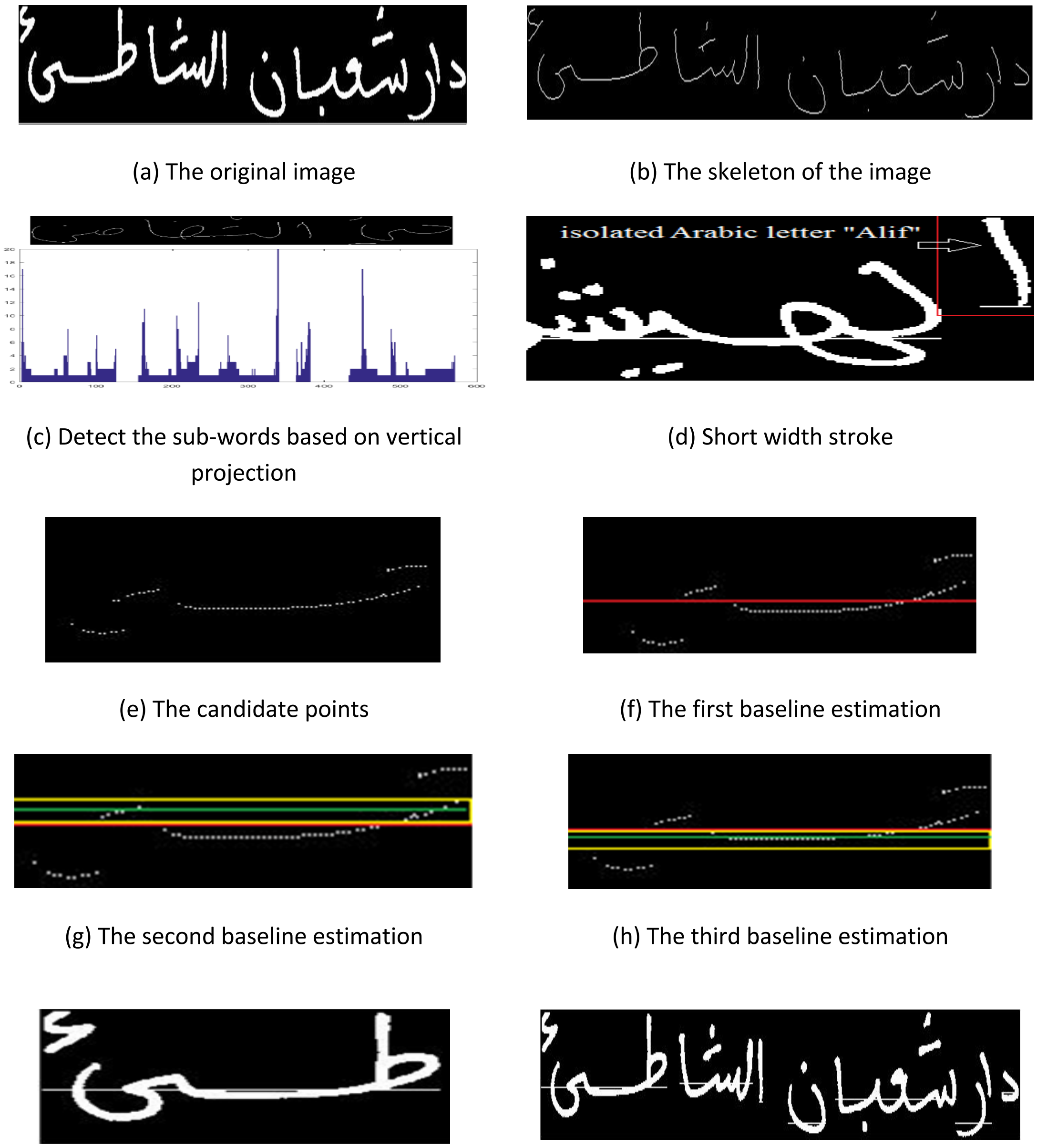
i. Read the text image and extract the skeleton of the handwritten text.
ii. Extract the sub-word based on the vertical histogram projection.
iii. If (the width of the sub-word) ≤ (1/25 * the width of the image),
Then this segment includes the isolated Arabic character "aleef"(ا),
therefore, the baseline = the lower edge of the character "aleef" (ا).
Else in the lower three quarters of the image, detect each pixel that has more than one neighbor, as a candidate point.
iv. Calculate the average for the vertical coordinate of all candidate points and draw a horizontal line based on this average. This horizontal line is the First Baseline Estimation (FBE).
v. In the region located from the FBE to 9 lines above FBE, calculate the average of the vertical coordinate for all candidate points and draw a horizontal line based on this average. This is the Second Baseline Estimation (SBE).
vi. In the region located from the FBE to 9 lines under FBE, calculate the average of the vertical coordinate for all candidate points and draw a horizontal line based on this average. This is the Third Baseline Estimation (TBE).
vii. The best baseline is the maximum value of horizontal projection for three baseline estimations.
viii. Move to the next sub-word, and repeat from step iii.
ix. Stop after handling the last sub-word.

Figure 1 shows the step by step illustration of the main processes involved and figure 2 shows the flowchart of this algorithm. In the first attempt, this algorithm was applied to an image without segmentation to extract the sub-words, where in the first attempt, only one baseline is detected in the image for all sub-words. The algorithm produces encouraging results in most of the images, where one of the three baselines (FBE, SBE, TBE) is overlapped with the real baseline. However, a skew which is produced by the differences between the height of sub-words, makes this algorithm fail at one or more sub-words in the same image. Figure 3(a) shows the results of baseline detection of the first attempt, where the best baseline crosses the real baseline just in the region located in the red rectangle highlighted in this figure, and the detected baseline of the regions highlighted by the red and oval colored circles are actually not an accurate baseline. In the figure 3(b), it shows the second attempt, where the image shows three different detected baselines, each one is the best for its sub-word. In this second attempt, best separated baselines were able to be detected for each sub-word after segmenting the image.

Therefore, vertical segmentation is an important task, to avoid the wrong detection of each sub-words. To detect the segment which includes the sub-word, the summation of the pixels values for each column was calculated and saved in an array. If the index includes zero and the next index includes a positive number is the beginning of the sub-word. If the index includes a positive number and the next index includes a zero, it is detected as the end of the sub-word.

For each segment, the algorithm was applied to detect the baseline. After that this algorithm faced two issues. The first is the wrong vertical segmentation and the second is the short width of the sub-word. The wrong vertical segmentation occurred because of the sub-words overlap, where two sub-words appear as one sub-word. The second problem is the short width segment, exactly in the isolated character aleef (ا). In general, this segment does not include branching points because it is a vertical character. This problem was solved by detecting the short-width segment. If the width of the segment is less than the image width divided by 25, this segment includes isolated character aleef

(ا). So, in this segment, the baseline is located at the bottom of the stroke. Figure 3(b) shows the baseline of the short-width segment.



(a) The original image

(b) The skeleton of the image

(c) Detect the sub-words based on vertical projection

(d) Short width stroke

(e) The candidate points

(f) The first baseline estimation

(g) The second baseline estimation

(h) The third baseline estimation

(i) The actual baseline of the sub-word

(j) All baselines of all sub-words

Fig. 1. The step by step illustration of the proposed method

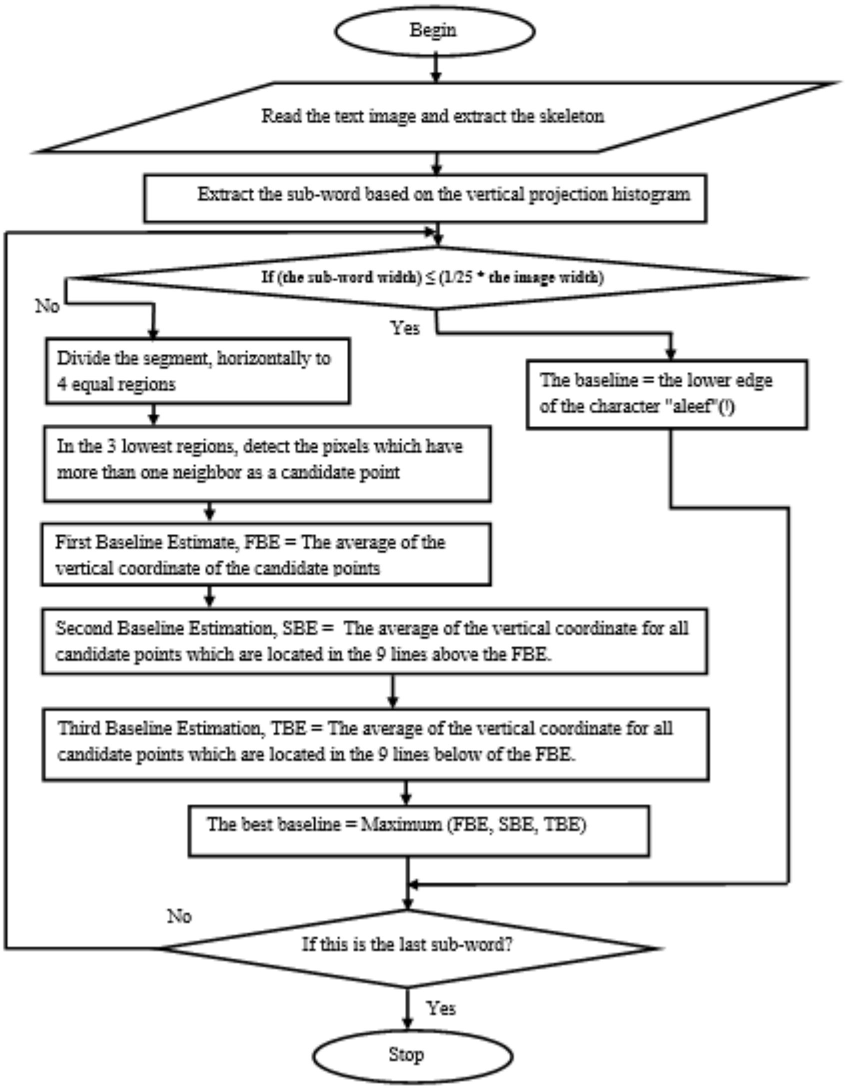


Fig. 2. The flowchart of the proposed algorithm

(a) Only a single baseline is detected in the first attempt. (b) Several baselines were detected in the second attempt.

Fig. 3. The results of the first baseline detection algorithm and the proposed algorithm.

4. Experimental Setup

In this paper, we used the IFN/ENIT handwritten Arabic benchmark database. IFN/ENIT database contains 26,549 Arabic handwritten text images. In these Arabic handwritten images, each image may include one or more Arabic words. It was written by 411 different writers. The texts in this database are the names of Tunisian towns and villages. This database was built by the Institute of Communications Technology (IFN) at Technical University Braunschweig in Germany and the National School of Engineers of Tunis (ENIT) in 2002. IFN/ENIT database is the most popular handwritten

Arabic database and been used by many researchers [36]. IFN/ENIT database includes 115585 sub-word and 212211 characters [39]. It is accredited as a benchmark handwritten Arabic text database. IFN/ENIT provides a free demo-sample with 569 images. Based on the review of the previous baseline detection methods, it should be highlighted that the authors of most of the previous methods have used different numbers of images to test their methods. The IFN/ENIT demo sub-database is employed in this work because it has been used by many other researchers in baseline detection as well as this database contains all challenges in Arabic baseline detection.

5. Results and Discussion

As previously mentioned, the IFN/ENIT demo sub-database includes images representing all challenges of Arabic baseline detection. Therefore, this sub-database images can be used to test the the performance of the proposed method for Arabic handwritten baseline detection. The resulted images showed that this method was not affected by the baseline challenges. But in a very rare case, it was affected by the big diacritics such as the "hamza" if it was written in big size and under the first quarter.

The proposed algorithm developed in MATLAB and was applied to the test the benchmarked images. The ground truth of the baseline which has been set by the IFN/ENIT has not been used in this study because it is not accurate as reported by Pechwitz and Maergner [26]. This inaccurate estimation of the ground truth for the baseline is due to the technique use for estimation is using three different estimates. To resolve this issue, Boukerma and Farah [31] made a manual estimation of the baseline and thus produced more accurate results as compared to the original ground truth dataset. Therefore, performance evaluation in this paper uses the ground truth dataset produced Boukerma and Farah [35] for performance evaluation of the proposed method.

The number of pixels between the manual estimation sub-word baseline (the actual sub-word baseline) and the sub-word baseline produced by the proposed algorithm was calculated manually. This number known as the error value, E in baseline detection. The error value was calculated for each sub-word. Then, the error average for all of the sub-words in the same image was calculated. Finally, the average of E for all images will be calculated. The Image Average Error (*IAE*), I is the average of the error value for all sub-words baseline detection in the same image and can be calculated using the following formula:

$$I = \frac{1}{S} * \sum_{1}^{S} E \qquad (1)$$

where S is the number of sub-words in the image and E is the error value of each sub-word baseline detection. The Total Average Error (*TAE*), T for all images that represents the average error of all images average error of the baseline detection can be calculated using the following equation:

$$T = \frac{1}{n} * \sum_{1}^{n} I \qquad (2)$$

where n is the number of all images and I is the average error value of all sub-words baseline detection in the same image.

We have run the experiment using the IFN/ENIT demo sub-database and used the proposed baseline detection algorithm. From the experimental runs, the maximum value of I is 24 pixels and the minimum value is 0 pixel. The value of T obtained is 3.394. The number of all sub-words in all of the images is 2133 sub-words. The error values E obtained the proposed algorithm is between 0 pixel to 46 pixels. The proposed algorithm produces 59% error value *E* for 0 pixel, 86.91% error value *E* for 10 or less pixels, 92.92% error value *E* for 15 or less pixels and 98.78% error value *E* for 25 or less pixels. The number of all sub-words which have error value *E* more than 10 pixels was 279 from 2133 sub-words. These results show a significant improvement of the proposed method as compared to all three other benchmarks methods. The detail of these results is shown in Table 1 where the results produced by this proposed method were compared with three other established methods for baseline detection.

Most of the previous baseline studies are based just on the number of error pixels in order to evaluate the accuracy of their methods. In this paper, we proposed a new criterion. This criterion is the ratio between the number of error pixels and the height of the image. We think this criterion is more appropriate because there are big differences between the height of the images where the maximum value of the image height is 163 pixels and the minimum value is 47 pixels.
The ratio of sub-word baseline detection error, r is defined as follows:

$$r = \frac{E}{h} \quad (3)$$

where *h* is the image height and E is the error value of each sub-word baseline detection.
The average ratio error of all sub-words in the dataset, R is defined as follows:

$$R = \frac{1}{N}\sum_{1}^{N} r \quad (4)$$

where *N* is the number of the sub-words. In the proposed method, the average ration error, R is 3.6%. Figure 4 shows some of the resulted images produced by this proposed baseline detection algorithm.

Table 1
A comparison between the proposed method and the previous established methods which used the same dataset, based on the error value.

Methods	Error value, *E*	0	5	10	15	20	25
Pechwitz and Margner [26]		0.86	22.6	48.69	65.21	79.13	86.08
Ziaratban and Faez [31]		47.39	4.56	85.33	91.82	92.72	92.85
Boukerma and Farah [35]		0.97	30.89	69.11	87.19	94.06	97.68
Al-Khatatneh *et al.*, [19]		2.6	30.43	62.6	84.34	90.43	92.17
The proposed method		58.6	74.26	86.91	92.92	97.32	98.78

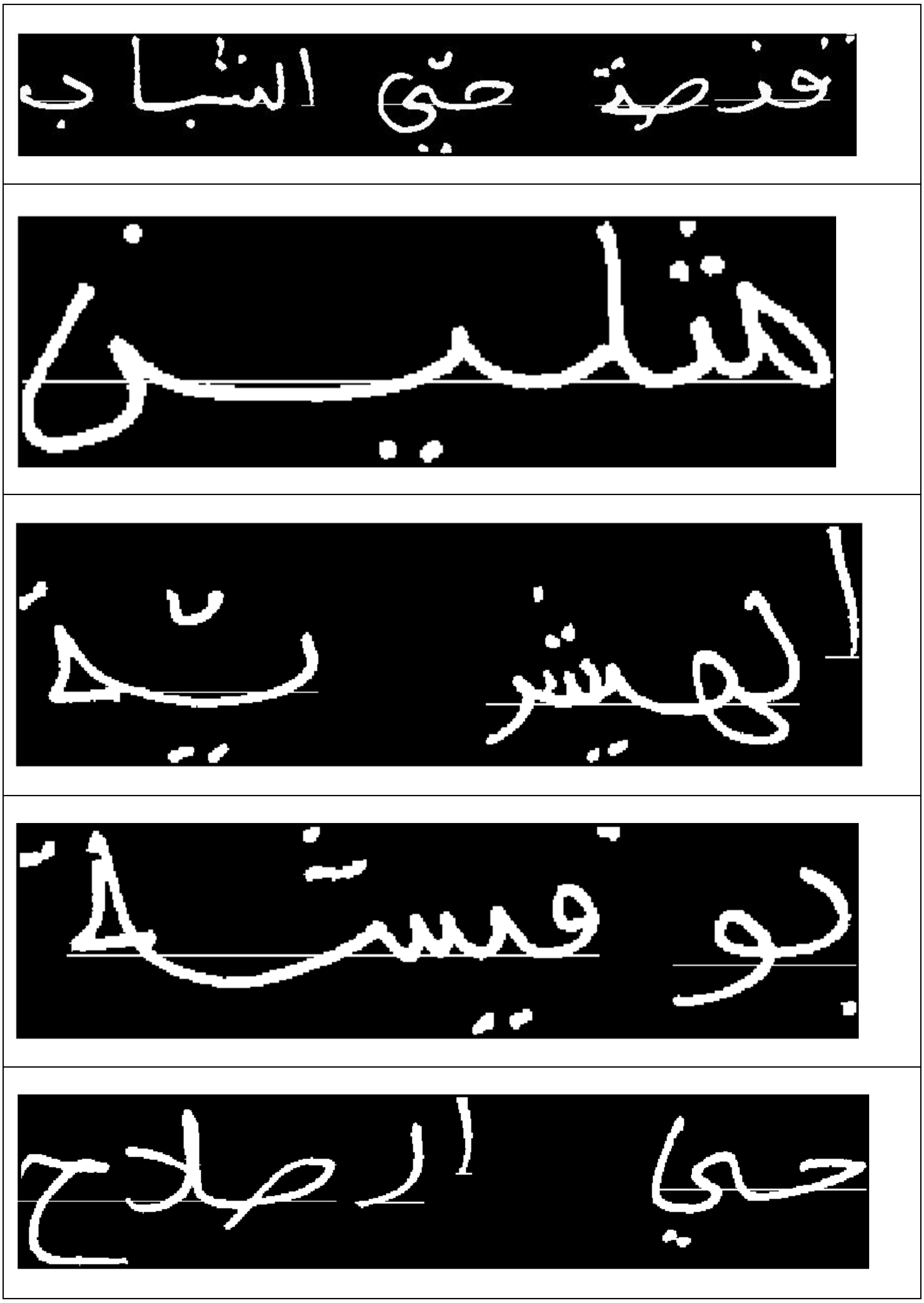


Fig. 4. Some sample baseline detection results produced by the proposed algorithm

6. Conclusion and Future Work

This paper presented a novel algorithm for baseline detection in the Arabic handwritten text. This proposed method is based on the text image skeleton and candidate points. This method uses global features thus avoiding training to detect the sub-word baseline for an unlimited number of words. In this work, the image was divided into four equal horizontal areas. The study confirmed that the baseline is always in the lowest three quarters, often in the second or third quarters. The resulted images from this proposed method showed that this method was not affected by the baseline challenges. This proposed method is also not affected by the sub-word, skew, slant, and other challenges. However, in a very rare case, it was affected by the big size diacritics such as the "hamza" "ء" if it was written in big size font and under the first quarter.

In general, the proposed algorithm achieved very encouraging results. However, we still need to improve the segmentation to detect the sub-word with more accuracy where the vertical projection cannot handle the overlapping of the sub-words. To extract the sub-words, we postulated that the contour is a very good alternative method. The contour method may be more accurate than the vertical projection diagram. Though the problem of sub-word detection appears just in a small number of images, notwithstanding it still need to be solved. Based on the high accuracy baseline detection of this method it will be very useful to use it in other tasks of Arabic handwriting recognition, like skew correction, features extraction and others.

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