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Text-line Segmentation Techniques for Arabic Handwritten Documents: A Review

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Abstract In this paper, a review of text line segmentation is conducted; more specifically, the focus was on Arabic handwritten documents. Arabic handwritten has a lot of difficulties when it comes to segmentation since the handwriting styles vary from one person to another, not to mention the skewness or inclined text-lines that might appear in the document that makes it difficult to implement text-line segmentation on it, along with diacritics marks that can also pose intricacies for the segmentation process. Therefore, in this research a general review about the related work that has been done in this field is first conducted, and the miscellaneous text-line segmentation algorithms used in recent years are reviewed. Moreover, comprehensive techniques for Arabic handwritten text-lines segmentation are presented, elaborating the results of each method used along with datasets type. Finally, this review paper underscores the continuous need for innovative solutions that can handle the complexities of text-line segmentation in Arabic handwritten documents, emphasizing the importance of pattern recognition and computer vision techniques. This will pave the way for researchers to build upon this work and invent robust new techniques to solve this problem in the future.

Keywords Text-line Segmentation, Arabic Text-lines, Arabic Handwritten, Image Segmentation, Image Processing

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1. Introduction

*T*ext-line segmentation is generally considered as preprocessing steps for tasks like printed character, skew correction and handwritten recognition. Frequently, a line segmentation engine is utilized prior to character recognition. Character segmentation and identification accuracy are highly dependent on the line segmentation engine's performance [1]. Since text-line segmentation acts as a bridge between word segmentation and page analysis, it is essential to layout analysis. For example, if we have the text-lines, we can segment them further or group them into zones according to how comparable their orientation and alignment are. words are formed from text-lines. Text-lines are therefore vital for understanding the hierarchy of document layouts [2]. Furthermore, there is still a significant challenge when to segment text-lines in handwritten document due to variety in handwriting styles [3], irregular spacing and potential overlapping components. In contrast, line segmentation in machine-printed documents is normally easier because of uniform nature and the consistent of printed text, with regular spacing and a clear baseline. In addition, Arabic document contains abundant of dots, strokes and diacritics that are added to the top or the bottom of the Arabic script to give a certain meaning [4]. In such documents, a connected component might be a whole word, a character, a sub-word, a dot or a stroke, the presence of these objects make the segmentation process more challenging. The figures below show an example of line segmentation in Arabic handwritten text.

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(a) (b)

Figure 1. (a) Original Image (b) Line Segmented Image

2. Related Work

Many studies of line segmentation are published for different languages such as Arabic, Urdu and Chinese. However, the focus will extensively be on the line segmentation in Arabic-handwritten and machine-printed documents along with the limitations of handwritten documents which will be emphasized in this article. Be that as it may, one way to consider a document is as an organization of text-lines, words, characters, pages, and zones in a hierarchical structure. This hierarchical structure is attempted to be extracted from an image representation by layout analysis [5]. Previous work on machine printed document analysis relies on a large gap between neighboring regions and homogeneity inside a region to segment a document at a specific level [6]. Prior work on layout analysis often employed two approaches: top-down and bottom-up [7]. Connected components are grouped into lines in the bottom-up paradigm, whereas the lines are divided into zones, and so on. A document page is initially divided into zones under the top-down methodology, and then each zone is further divided into lines, and so on. Even though machine printing techniques are advanced, analyzing a freestyle handwritten manuscript is far more difficult for several reasons, including page-level non-Manhattan layout. Simple criteria, including grouping based on the geometric relationships of nearby components or using curvilinear text-lines, cannot handle the uneven page layout. Linear approximation and regression are not always correct in general, Connected words. It is not simple to examine, filter, and process the linked components because of the connectedness between characters and words; and Variation in character size. Character sizes could change significantly, even within the same page. It makes it difficult to estimate the dominant character size, which is a crucial factor in text-line segmentation using a bottom-up linked component approach [8]. Table 1 presents the miscellaneous text-line segmentation algorithms used in recent years.

Table 1. Miscellaneous algorithms for text-line segmentation used in recent years

Paper	Year	Dataset	Algorithms	Findings
[9]	2019	Handwritten Persian database	A novel projection profile histogram method	The proposed method showed superiority in extracting lines in the text images with an accurate rate of 85.5%
[10]	2020	Urdu handwritten and printed text	Counting pixel approach	The proposed technique is tested on printed and handwritten text and induced an accuracy rate of 98.3% and 96.7% respectively.

[11]	2020	Mushaf Al-Quran Images	Hough Transform	The proposed method is used to detect lines for calculating skew detection. It showed a high accuracy rate of approximately 90%.
[12]	2020	ICDAR 2017 and ICFHR 2010 handwritten text datasets	Unsupervised deep learning	The UTLS method that was proposed showed good results, with a 93.78% F-measure on the VML-AHTE dataset. It did better than supervised methods when it came to recognition accuracy. It also did well on ICDAR 2017 (up to 95.5% Pixel IU) but had some difficulties with the very different text lines in ICFHR 2010 (72.36% F-measure).
[13]	2020	cBAD datasets	Learning-free method	The method proposed accomplished 99.46% Line IU and 97.50% Pixel IU on the DIVA-HisDB dataset, outperforming previous approaches. It also performed well on cBAD datasets with F1-score of 86.38%.
[14]	2020	MIDV-500 and Census 1961 Project datasets	CNN framework: Artificial intelligent neural network and dynamic programing	The proposed solution in this paper showed a high accuracy rate of 96.69% on natural datasets even if it is being trained on purely artificial data.
[15]	2021	Uchen Tibetan documents	Connected component and local baseline	The proposed method had a 99.45% F1-score beating earlier methods. It dealt well with distorted, skewed, and incomplete strokes showing it was reliable in dividing text lines. It also made a baseline detection 100% accurate.
[16]	2021	RIMES, IAM and READ	A unified end to end model	The proposed method performed well for three datasets and the error rate for each are: 1.91% for RIMES, 4.45% for IAM and 3.59% for READ.
[17]	2022	Handwritten documents images	Unsupervised learning approach	The proposed technique achieved a recall of 98.11%, precision of 97.92%, F1-score of 98.02%, and works well in documents with globally monotonic text-line patterns even with contacting components, and slightly skewed text-lines.

[18]	2022	IAM dataset	Neural network (non-recurrent approach)	The proposed method demonstrated a character error rate of 4.67% and word error rate of 15.45%, thus it surpassed the recurrent seq2seq model.
[19]	2023	Malayalam handwritten documents	horizontal and vertical projections	The method achieves a MatchScore of 85.5%, recognition accuracy of 99.39%, detection rate of85.5%, and F-measure of 91.92%, outperforming existing algorithms.
[20]	2024	Iranian newspapers and PRIMA	Advanced document layout analysis (DLA)and voting systems with innovative text-line detection (TLD) techniques	The results obtained achieved a 2.8% accuracy improvement over Tesseract-OCR 5.1.0 on the given datasets.
[21]	2025	recently published Indic and Southeast Asian literature	LineTR, a two-stage, dataset-independent method for text-line segmentation in old manuscripts	The results demonstrate effectiveness of unified model and zero-shot interference. It also achieved scores up to 0.82 in IoU (intersection over union).

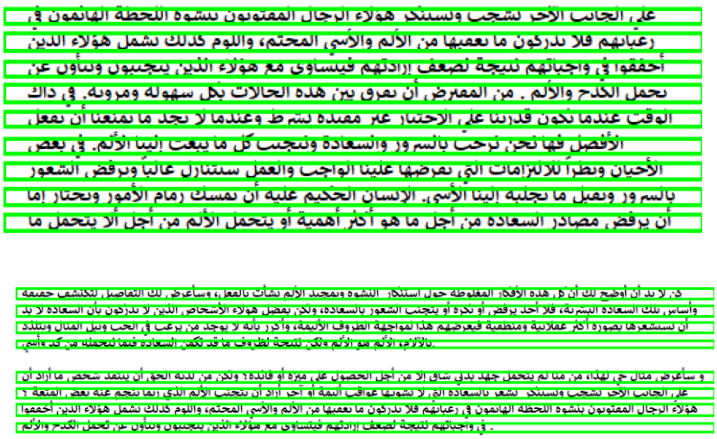


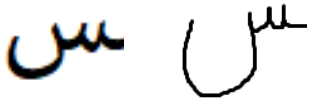
Figure 2. Text-line segmentation for printed documents

2.1. Text line segmentation challenges in Arabic written

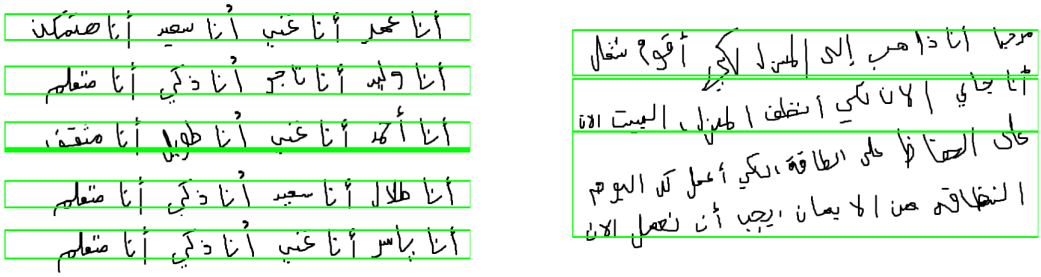
From the beginning of time handwritten language has been an inevitable aspect of human life. It is the classic form that will always remain, no matter how digital the world becomes. However, handwriting varies especially when it comes to the cursive script, where the writer's style of handwritten characters size is different [22]. Moreover, Arabic-handwritten has unique characteristics such as diacritic marks, strokes and cursive nature. Henceforth,

Arabic handwriting was considered a challenging task in computer vison [23]. Each person has his own way of writing depending on shape of letter, habits, education, mood, health and other relative conditions of the writer [24]. In addition, each character in Arabic can sometimes be transformed into up to four different forms as illustrated in Table 2.

Table 2. Printed and Handwritten Arabic Letters

Letter	Beginning Word		Middle Word		End Word	
	Printed	Handwritten	Printed	Handwritten	Printed	Handwritten
خ	خ		خ		خ	
س	س		س		س	

Segmentation often entails dividing a handwritten document into its constituent text-lines and words. Finding text-lines and words in Arabic-handwritten texts is still difficult, nevertheless. Text-lines present difficulties such as different skewing angles between lines and touching adjacent text-lines, but words are frequently segmented into letters, sub-words, and words. The skewness of scripts varies, and there are regular gaps between words and subwords. Figure 3 shows an example of straight text-line and an inclined text-line, for the first, it is much easier to distinguish between the lines as the text typically is well aligned horizontally but separating diacritics from the actual text remains a challenge in most cases. While for the skewed or the inclined text-line is difficult to detect the lines due to the fact that it appears at various skews which makes the characters alignments uneven and hard to process. Furthermore, the inclined lines make the diacritics and characters overlap more frequently, not to mention the irregular spacing between words and letters that might exacerbate on the inclined texts, making the segmentation process difficult.



(a) (b)

Figure 3. a) Straight text-lines, b) Skewed/Inclined and connected text-lines

2.2. Framework of Text-Line Segmentation in Arabic-handwritten

Pre-processing is an important stage in the image processing process. The primary duty for this phase is getting the document ready for processing. Nonetheless, the Pre-processing stage includes the subsequent subsequence phases: The segmentation process, which divides an image into several sections, makes an image representation more understandable and simpler to analyze. The pre-processing and segmentation stages are depicted in Figure 3. The feature extraction phase focuses on dimensionality reduction, which is the process of breaking down a set of initial raw variables into smaller, more manageable groups while maintaining accurate and comprehensive representation of the original dataset. The feature selection phase, also known as the selection of variables or attributes, is the process of choosing pertinent features, such as predictors and variables, from a subset. The classification process involves categorizing photos into several predetermined groups [25]. All these stages are very crucial as if an error occurred in one of them, it would extremely affect on the succeeding ones. However, in this paper the concertation will be on segmentation phase as our main idea is segmenting text-line from Arabic-handwritten documents, the steps required to perform these operations are elaborated in the following Figure 4.

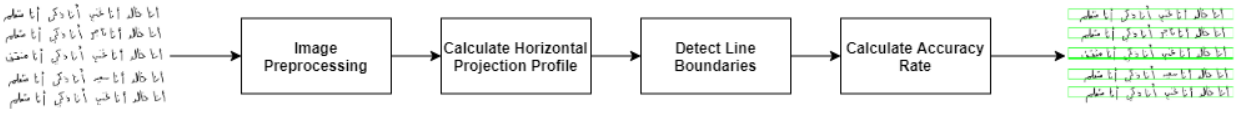


Figure 4. Text-line segmentation framework

- Image data: Collected images from diverse sources of Arabic-handwritten that have various writing styles are uploaded first to start the image processing for test-line segmentation.

- Image preprocessing: As the image is inserted, the noise in the image will be removed and grayscale conversion will be performed to make easy implementing binarization and reducing the color of the image. Following that is converting to binary which has two values for each pixel which are black and white to identify the important parts of the image. **- Text-lines segmentation method:** After the image is converted to binary, the proposed method will take place to perform the desired task it is assigned to. This task could be any, however in this case text-line segmentation technique is implemented to segment the image into distinguishable lines, these techniques could be Projection Profile, Hough Transform, connected component, CNN framework etc.

- Detecting Text-lines: The proposed method's task is to identify the start and end of each line of text. This is crucial for precisely separating lines before further analysis. The process also involves detecting lines in upper and lower limits of each text-line to separate them from adjacent lines. However, this might face a lot of challenges such diacritics marks interference that might cause errors in segmentation, not to mention the cursive nature of Arabic text especially handwritten that make it difficult to distinguish between the words or lines.

- Image output: Finally, after the above-mentioned process is taken, the image data will be generated to eventually segmented text-line in Arabic-handwritten.

2.3. Summary of Previous Text-Line Segmentation Techniques for Arabic Handwritten

There are numerous techniques for text-line segmentation in Arabic-handwritten documents that have been proposed in past years. Although there are not yet fully dependable segmentation methods for text-line segmentation in Arabic handwriting documents due to the variety of writing styles and diacritics marks that complicate the segmentation process, in this section a summary of literature review below is presented in Table 1 discussing the previously used segmentation techniques along with their results and datasets type. These methods serve different purposes in relation to Arabic-handwritten text-line segmentation, aiming to contribute to a better solution in this field.

Table 3. Summary of previous text-line segmentation techniques for Arabic handwritten

Ref	Year	Technique	Datasets	Results
[26]	2007	bivariate Gaussian densities and piece-wise Projection profile	Arabic, English and children handwritten	The proposed method was tested on 120 Arabic-handwritten images and obtained an accuracy of 98.62% of correct extracted text-lines showing incredible improvements over the previous methods
[27]	2007	K-means clustering and vertical/horizontal projection profiles	Handwritten or printed historical Arabic documents	The proposed method has achieved 96% of accuracy rate on set of 100 Arabic historical documents
[28]	2008	Projection profile	50 handwritten Arabic documents that contain 150 text-lines	The proposed scheme evaluated on 50 documents with an accuracy that reach about 97.6%
[29]	2009	A generalized adaptive local connectivity map using Steerable directional profile	DARAPA MADCAT Arabic-handwritten document database	The approach can successfully isolate the handwritten Text-lines correctly, even on challenging images
[30]	2009	Morphology analysis	100 documents of Arabic-handwritten	The result obtained is equal to 96.88%, and 3.12% error rate
[31]	2010	Unsupervised method, block covering analysis	Historical Arabic-handwritten documents	The technique achieved high accuracy rate of 95% extracting text-lines
[32]	2010	Graph-based method	Arabic-handwritten images	The method demonstrated robustness in terms of line segmentation of 96% of accuracy rate
[33]	2011	Dynamic programming	Online Arabic sentence datasets (OHASD)	The proposed method showed better results and got 94% of accepted text-line segmentation of total number of documents
[34]	2012	Morphological dilation with a dynamic adaptive mask	CENPARMI Arabic-handwritten database	The proposed approach demonstrated effectiveness with precision and recall rates of 96.3% and 96.7%
[35]	2014	Horizontal projection profile analysis (HPP)	Arabic-handwritten database (AHDB)	The proposed method achieved a promising result of 84.8% of correct segmentation rate
[36]	2014	Line height method (LHM)	Arabic-handwritten documents	Successful results were obtained for line segmentation in Arabic-handwritten
[37]	2014	A novel approach based on adaptive striping, dilation, projection, smoothing	Scanned manuscripts of Arabic Persian handwritten	The approach has shown an accuracy rate that ranges between 91% and 97%

[38]	2014	Mathematical morphology (MM), outer isothetic cover (OIC), MM-OIC and HT-MM	IFN/ENIT, BSB and KSU databases, Arabic-handwritten	The results obtained for the two proposed methods state that the average rate of text-line segmentation for M-OIC is 75% and 45% for HT-MM method
[39]	2015	Hybrid method, line classification and sliding window	Arabic-handwritten documents	The three methods combined have achieved an average execution time of 12s and result of 90%
[40]	2015	Connected component analysis	Arabic-handwritten documents	The proposed method obtained 97.4% and 94.3% of F1-score, for MS-threshold values are 90% and 95%
[41]	2016	Connected components analysis	Arabic-handwritten documents	The approach demonstrated a promise for extracting curved lines in Arabic-handwritten with F1-score of 97.4% and 94.3%
[42]	2017	Watershed transform	Proximity datasets, Arabic-handwritten	The proposed method has achieved a segmentation rate 93% and 95% of matching score
[43]	2018	Neural networks, RU-net	Arabic-handwritten from KHATT standard Arabic database	The proposed technique achieved 96.7% of the correct segmented lines.
[44]	2018	Horizontal projection profile analysis (HPP)	Arabic-handwritten database (AHDB)	The result obtained for line segmentation has reach to segmentation rate of 99%
[45]	2018	Seam carving	Proximity datasets, Arabic-handwritten	The proposed technique showed a line segmentation rate of 97.5% and matching score of 90%
[46]	2019	Deep learning, RU-net	Arabic-handwritten from KHATT standard Arabic database	The method achieved success rate no less than 97.7% for text-lines
[47]	2019	Hough transform (HT)	Arabic handwriting datasets collected from IFN/ENIT and AHDB	The proposed work achieved 98.9% of accuracy rate for text-line segmentation
[48]	2019	Hough transform	Arabic handwriting datasets collected from IFN/ENIT and AHDB	The proposed method has achieved 98.9% on AHDB and 97.4% on IFN/ENIT datasets
[49]	2019	Horizontal projection profile analysis (HPP)	Arabic-handwritten database (AHDB)	The method showed a promising result of 99% success rate of line segmentation
[50]	2020	AR2U-net, neural network	BADAM, public datasets for baseline detection in Arabic manuscripts	The proposed model has achieved best performance of 0.932% of precision rate

[51]	2020	Multi-agent system	Arabic-handwritten manuscripts from several sources like KHATT and HAPD datasets	The result obtained by the proposed method is satisfactory with F1 score exceeds 99% with both KHATT and HAPD datasets
[52]	2020	VML-UTLS, unsupervised segmentation	VML-AHTE, Arabic-handwritten text-line extraction	The proposed method achieved a superior performance in text-line segmentation even over supervise methods
[53]	2024	Horizontal projection profile and path planning	KFUPM and KHATT datasets of Arabic-handwritten	The technique worked well for segmenting straight or skewed lines in Arabic-handwritten text

3. Conclusion

This paper examines text line segmentation techniques for Arabic handwritten documents while discussing the specific difficulties that cursive writing and skew deformations, along with diacritics, introduce. The study evaluates recent algorithms along with methods to explain both advancements and constraints within this field. Numerous promising techniques exist, yet they face severe difficulties because of inconsistent writing styles and diverse document quality, together with overlapping document components. Each data segmentation method has distinctive theoretical foundations, such as projection-based methods, connected components, and learning-based models, which demonstrate that none provides superior results across the board for every dataset. Hybrid models developed to combine the advantageous aspects of various different techniques represent the main emphasis of the paper. Despite the progress made, the comprehensive review discussed throughout this article relies heavily on reported performance metrics without standardized experimental conditions, which could somehow impact the objectivity of the comparative analysis, potentially leading to incomplete performance claims between studies. Since there is still not a one-size-fits-all answer that can tackle all the issues in splitting up handwritten Arabic text lines. For future work, researchers should consider creating hybrid models. These models could combine the best parts of old-school and existing methods like projection profiles and Hough transform with state-of-the-art methods such as CNNs and transformers. This combination could lead to more precise and flexible text splitting.

REFERENCES

1. A. Zahour, L. Likforman-Sulem, W. Boussalaa, and B. Taconet, "Text line segmentation of historical arabic documents," in *Proc. Int. Conf. Doc. Anal. Recognition, ICDAR, vol. 1, no. July*, pp. 138–142, 2007.
2. Y. Li, Y. Zheng, D. Doermann, and S. Jaeger, "Script-independent text line segmentation in freestyle handwritten documents," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 30, no. 8, pp. 1313–1329, 2008.
3. A. A. Sheikh, M. S. Azmi, W. A. K. Abuain, and M. A. Aziz, "Segmentation techniques for arabic-handwritten: a review," *Int. J. Electr. Comput. Eng.*, vol. 14, no. 2, p. 1834, 2024.
4. T. A. K. Abuain, "Contour-based diacritics detection for enhanced arabic text image processing," *J. Theor. Appl. Inf. Technol.*, vol. 102, no. 18, pp. 6792–9800, 2024.
5. A. K. Jain and B. Yu, "Document representation and its application to page decomposition," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 20, no. 3, pp. 294–308, 1998.
6. J. Liang, I. T. Phillips, and R. M. Haralick, "Performance evaluation of document structure extraction algorithms," *Comput. Vis. Image Underst.*, vol. 84, no. 1, pp. 144–159, 2001.
7. G. Nagy, "Twenty years of document image analysis in pami," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 22, no. 1, pp. 38–62, 2000.
8. L. O'Gorman, "The document spectrum for page layout analysis," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 15, no. 11, pp. 1162–1173, 1993.
9. A. Zohrevand, J. Sadri, Z. Imani, and M. R. Yeganezad, "Line segmentation in persian handwritten documents based on a novel projection histogram method," *4th Int. Conf. Pattern Recognit. Image Anal. IPRIA*, vol. 2019, pp. 70–74, 2019.
10. S. Malik *et al.*, "An efficient skewed line segmentation technique for cursive script ocr," *Sci. Program.*, vol. 2020, 2020.

11. S. S. Bafjaish, A. Ramzani, M. Nasser, M. Sanusi, and H. Mahdin, "Skew detection and correction of mushaf al-quran script using hough transform," *Int. J. Adv. Comput. Sci. Appl.*, vol. 9, no. 8, pp. 402–409, 2018.
12. B. K. Barakat *et al.*, "Unsupervised deep learning for text line segmentation," in *Proc. - Int. Conf. Pattern Recognit., no. d*, pp. 2304–2311, 2020.
13. B. K. Barakat, R. Cohen, A. Droby, I. Rabaev, and J. El-Sana, "Learning-free text line segmentation for historical handwritten documents," *Appl. Sci.*, vol. 10, no. 22, pp. 1–19, 2020.
14. Y. S. Chernyshova, A. V. Sheshkus, and V. V. Arlazarov, "Two-step cnn framework for text line recognition in camera-captured images," *IEEE Access*, vol. 8, pp. 32587–32600, 2020.
15. P. Hu, W. Wang, Q. Li, and T. Wang, "Touching text line segmentation combined local baseline and connected component for uchen tibetan historical documents," *Inf. Process. Manag.*, vol. 58, no. 6, p. 102689, 2021.
16. D. Coquenet, C. Chatelain, and T. Paquet, "End-to-end handwritten paragraph text recognition using a vertical attention network," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 45, no. 1, pp. 508–524, 2023.
17. A. Droby, B. K. Barakat, R. Saabni, R. Alaasam, B. Madi, and J. El-Sana, "Understanding unsupervised deep learning for text line segmentation," *Appl. Sci.*, vol. 12, no. 19, p. 9528, 2022.
18. L. Kang, P. Riba, M. Rusiñol, A. Fornés, and M. Villegas, "Pay attention to what you read: Non-recurrent handwritten text-line recognition," *Pattern Recognit.*, vol. 129, 2022.
19. P. P. V. and D. Sankar, "Handwriting-based text line segmentation from malayalam documents," *Appl. Sci.*, vol. 13, no. 17, 2023.
20. A. Fateh, M. Fateh, and V. Abolghasemi, "Enhancing optical character recognition: Efficient techniques for document layout analysis and text line detection," *Eng. Reports*, vol. 6, no. 9, pp. 1–26, 2024.
21. V. Agrawal, N. Vadlamudi, M. Waseem, A. Joseph, S. Chitluri, and R. K. Sarvadevabhatla, "Linetr: Unified text line segmentation for challenging palm leaf manuscripts," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 1531, pp. 217–233, 2025. 9 LNCS.
22. N. Alrobah and S. Albahli, "Arabic-handwritten recognition using deep learning: A survey," *Arab. J. Sci. Eng.*, vol. 47, no. 8, pp. 9943–9963, 2022.
23. N. Altwaijry and I. Al-Turaiki, "Arabic handwriting recognition system using convolutional neural network," *Neural Comput. Appl.*, vol. 33, no. 7, pp. 2249–2261, 2021.
24. A. Al-dmour and F. Fraij, "Segmenting arabic-handwritten documents into text lines and words," *Int. J. Adv. Comput. Technol.*, vol. 6, no. 3, pp. 109–119, 2014.
25. A. A. H. Hassan, W. M. Shah, M. F. Iskandar, M. N. Al-Mhiqani, and Z. K. Naseer, "Unequal clustering routing algorithms in wireless sensor networks: A comparative study," *J. Adv. Res. Dyn. Control Syst.*, vol. 10, no. 2, pp. 2142–2156, 2018. Special Issue.
26. M. Arivazhagan, H. Srinivasan, and S. Srihari, "A statistical approach to line segmentation in handwritten documents," *Doc. Recognit. Retr. XIV*, vol. 6500, p. 65000T, 2007.
27. A. Zahour, L. Likforman-Sulem, W. Boussalaa, and B. Taconet, "Text line segmentation of historical arabic documents," in *Proc. Int. Conf. Doc. Anal. Recognition, ICDAR, vol. 1, no. , 2007*, pp. 138–142, 10 2007.
28. N. Ouwayed *et al.*, "Multi-oriented text line extraction from handwritten arabic documents to cite this version: Hal id: inria-00347225 multi-oriented text line extraction from handwritten arabic documents." 2008.
29. Z. Shi, S. Setlur, and V. Govindaraju, "A steerable directional local profile technique for extraction of handwritten arabic text lines," in *Proc. Int. Conf. Doc. Anal. Recognition, ICDAR, no. i*, pp. 176–180, 2009.
30. N. Ouwayed and A. Bela, "Separation of overlapping and touching lines," *pp*, pp. 237–244.
31. W. Boussellaa, A. Zahour, H. Elabed, A. Benabdelhafid, and A. Alimi, "Unsupervised block covering analysis for text-line segmentation of arabic ancient handwritten document images," in *Proc. - Int. Conf. Pattern Recognit., no. August*, pp. 1929–1932, 2010.
32. D. Doermann, "Handwritten arabic text line segmentation using affinity," *pp*, pp. 135–142, 2010.
33. R. I. Elanwar, M. A. Rashwan, and S. A. Mashali, "On-line arabic handwriting text line detection using dynamic programming," *World Acad. Sci. Eng. Technol.*, vol. 50, pp. 582–587, 2011.
34. M. Khayyat, L. Lam, C. Y. Suen, F. Yin, and C. L. Liu, "Arabic-handwritten text line extraction by applying an adaptive mask to morphological dilation," in *Proc. - 10th IAPR Int. Work. Doc. Anal. Syst. DAS 2012*, pp. 100–104, 2012.
35. A. Al-dmour and F. Fraij, "Segmenting arabic-handwritten documents into text lines and words," *Int. J. Adv. Comput. Technol.*, vol. 6, no. 3, pp. 109–119, 2014.
36. M. A. Mohammed, M. R. Kumar, and R. Pradeep, "Text line segmentation of arabic-handwritten documents using line height method," *Int. J. Adv. Res. Comput. Sci. Softw. Eng.*, vol. 4, no. 11, pp. 170–174, 2014.
37. R. Shakoori, "A method for text-line segmentation for unconstrained arabic and persian handwritten text image," in *Proc. 2014 IEEE 15th Int. Conf. Inf. Reuse Integr. IEEE IRI 2014*, pp. 338–344, 2014.
38. S. S. Maddouri, F. Ghazouani, and F. B. Samoud, "Text lines and paws segmentation of handwritten arabic document by two hybrid methods," *2014*, vol. 1st Int. Conf. Adv. Technol. Signal Image Process. ATSIP 2014, pp. 310–315, 2014.
39. M. Younes and Y. Abdellah, "Segmentation of arabic-handwritten text to lines," *Procedia Comput. Sci.*, vol. 73, pp. 115–121, 2015. no. Awict.
40. Y. Boulid and A. Souhar, "Arabic-handwritten text line extraction using connected component analysis," *pp*, pp. 80–87.
41. Y. Boulid, A. Souhar, and M. Y. Elkettani, "Segmentation approach of arabic manuscripts text lines based on multi agent systems," *Int. J. Comput. Inf. Syst. Ind. Manag. Appl.*, vol. 8, pp. 173–183, 2016.
42. A. Souhar, Y. Boulid, E. Ameur, and M. Ouagague, "Segmentation of arabic-handwritten documents into text lines using watershed transform," *Int. J. Interact. Multimed. Artif. Intell.*, vol. 4, no. 6, p. 96, 2017.
43. A. Belabiod and A. Belaïd, "Line and word segmentation of arabic-handwritten documents using neural networks," 2018.
44. A. Lamsaf, M. Aitkerroum, S. Boulaknadel, and Y. Fakhri, "Lines segmentation and word extraction of arabic-handwritten text," *ACM Int. Conf. Proceeding Ser.*, pp. 1–7, 2018.
45. M. Daldali and A. Souhar, "Handwritten arabic documents segmentation into text lines using seam carving," *Int. J. Interact. Multimed. Artif. Intell.*, vol. 5, no. 5, pp. 89–96, 2019.

46. C. Neche, A. Belaïd, and A. Kacem-Echi, "Arabic-handwritten documents segmentation into text-lines and words using deep learning," *2019 Int. Conf. Doc. Anal. Recognit. Work. ICDARW*, vol. 6, p. 2019, 2019.
47. A. A. A. Ali and M. Suresha, *Efficient Algorithms for Text Lines and Words Segmentation for Recognition of Arabic-handwritten Script*, vol. 882. Singapore: Springer, 2019.
48. S. Mallaiah, A. Ali, and A. Ali, "Segmentation of handwritten text lines with touching of line," *Int. J. Comput. Eng. Appl.*, vol. 12, no. 6, pp. 1–12, 2019.
49. A. Lamsaf, M. Aitkerroum, S. Boulaknadel, and Y. Fakhri, *Text Line and Word Extraction of Arabic-handwritten Documents*, vol. Part. F1405: Springer International Publishing, 2019.
50. T. B. A. Gader and A. K. Echi, "Unconstrained handwritten arabic text-lines segmentation based on ar2u-net," in *Proc. Int. Conf. Front. Handwrit. Recognition, ICFHR, vol. 2020-Septe*, pp. 349–354, 2020.
51. M. Elkhayati, Y. Elkettani, and M. Mourchid, "A multi-agent approach to segment arabic-handwritten text lines," *Int. J. Cogn. Informatics Nat. Intell.*, vol. 14, no. 4, pp. 82–100, 2020.
52. B. K. Barakat *et al.*, "Unsupervised text line segmentation." 3 2020.
53. S. Aabed and A. Khairaldin, *An End-to-End, Segmentation-Free, Arabic-handwritten Recognition Model on KHATT An End-to-End, Segmentation-Free, Arabic-handwritten Recognition Model on KHATT*. no: June, 2024.