

Arabic Manuscript Author Verification Using Deep Convolutional Networks

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Abstract—Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

I. INTRODUCTION

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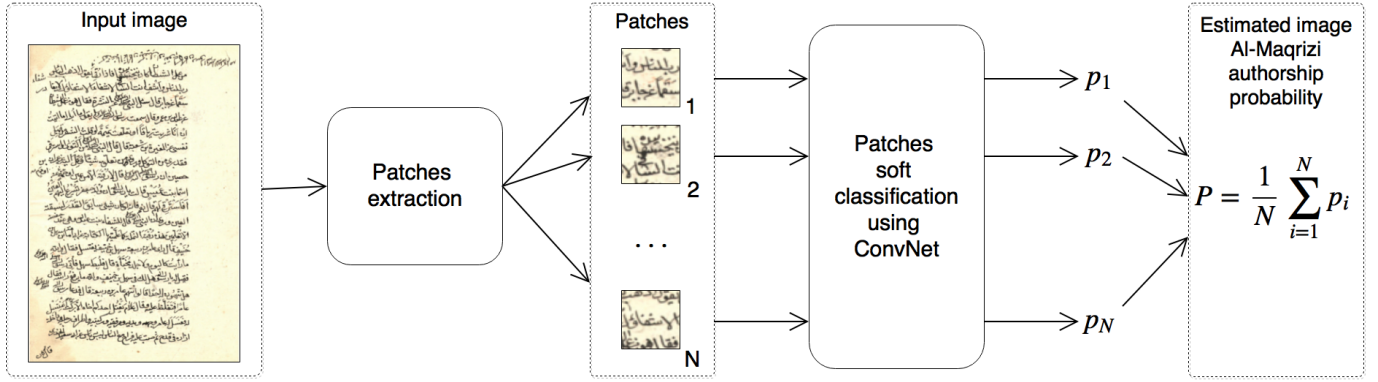


Fig. 1. Al-Maqrizi authorship soft classification pipeline

II. THE DATA

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III. THE METHOD

We consider author verification problem as a binary classification problem: Al-Maqrizi class denoted as 1 and non-Al-Maqrizi class denoted as 0. In this context our goal is to build a classification pipeline able predict the probability (*soft* classification) that given image belongs to the 1 (Al-Maqrizi) class. The entire Al-Maqrizi authorship classification pipeline illustrated at figure 1 consists of the following steps:

- 1) Image preprocessing.
- 2) Extracting patches from candidate image.
- 3) Patches soft classification using ConvNet .
- 4) Averaging predicted patches probabilities to produce overall candidate image Al-Maqrizi authorship probability.

Each of this steps are thoroughly described in the following sections.

[Describe image preprocessing]

A. Patches extraction

The patches extraction method generates a set of sub-images called patches from given image. The basic idea is that patch should represent small but yet meaningful part of image for the main purpose - authorship verification. We use two alternative methods for patches extraction described in following subsections.

1) *Sliding window based method*: This method splits given image by a grid of fixed cell size. Each cell further used as a patch. Figure ?? [add figure] illustrates the idea.

2) *Connected components based method*: This method uses following routine for patches extraction

- 1) Input image binarization using Otsu's filter [reference to Otsu filter paper].
- 2) Connected components extraction from binarized image using algorithm from [reference to connected components paper]. c
- 3) Too small, too big and too stretched connected components filtering using several empirical rules [specific rules description].
- 4) Outlier connected components filtering using DBSCAN [reference to DBSCAN paper] clustering algorithm.

- 5) Using remaining connected components bounding boxes as patches.

Example of connected components based patches show on figure ?? **[add figure]**.

It could be seen, that connected components based patches usually consist of one or few letters thus providing high robustness for different image scale and size in contrast to fixed-size sliding window patches. However, fixed-sliding patches contain much more information: several symbols from several lines, - a very important feature for the authorship verification.

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IV. RESULTS AND DISCUSSION

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V. CONCLUSION

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REFERENCES

- [1] M. Bulacu, L. Schomaker, A. Brink "Text-independent writer identification and verification on offline arabic handwriting," in *Proc. 9th International Conference on Document Analysis and Recognition, ICDAR*, Curitiba, 2007, pp. 769–773.
- [2] D. Fecker, A. Asi, W. Pantke, V. Mrgner, J. El-Sana, T. Fingscheidt "Document Writer Analysis with Rejection for Historical Arabic Manuscripts," in *Proc. 14th nternational Conference on Frontiers in Handwriting Recognition, ICFHR*, Crete, 2014, pp. 743–748.
- [3] Y. Lecun, Y. Bengio, G. Hinton, "Deep learning," *Nature*, no. 521, pp. 436–444, May. 2015.
- [4] Y. Lecun, L. Bottou, Y. Bengio, P. Haffner, "Gradient-based learning applied to document recognition," in *Proc. of the IEEE*, 1998, pp. 2278–2324.
- [5] A. Krizhevsky, I. Sutskever, G. Hinton, "ImageNet Classification with Deep Convolutional Neural Networks," in *Advances in Neural Information Processing Systems*, vol. 25, 2012, pp. 1097–1105.
- [6] C. Szegedy, W. Liu, Y. Jia, P. Sermanet, S. Reed, D. Anguelov, D. Erhan, V. Vanhoucke, A. Rabinovich, "Going deeper with convolutions," in *Proc. of the IEEE Conference on Computer Vision and Pattern Recognition*, Boston, 2015, pp. 1–9.
- [7] O. Granichin, V. Volkovich, D. Toledano-Kitai, *Randomized Algorithms in Automatic Control and Data Mining*. Springer-Verlag: Heidelberg, New York, Dordrecht, London, 2015, 251 p.