





The Internationl Conference on Intelligent Systems and Pattern Rocognition

16-18 October Hammamet (Tunisia)

Document analysis and recognition : The Deep Learning Era

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About me

Yousri Kessentini

- Assistant professor at CRNS
- Head of DeepVision research team
- More than 15 years experience in the document analysis & recognition
 - PHD in the university of Rouen
 - Post-doc Itesoft-LITIS
 - Researcher in CRNS



Certified as an official instructor & ambassador from NVIDIA Deep Learning Institute







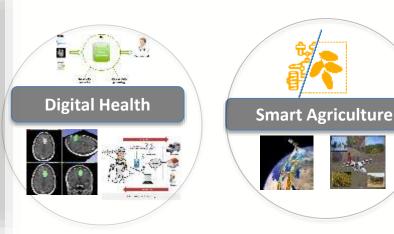
Digital research center of Sfax



• 11 000 m² / 165 researchers

Research Topics

- 1. Computer and distributed systems
- 2. Image and signal processing
- 3. Document and data analysis
- 4. Recognition of shapes and objects (3D)
- 5. Electronics and embedded systems
- 6. Computer Networks
- 7. Security of computer systems



Application Domains

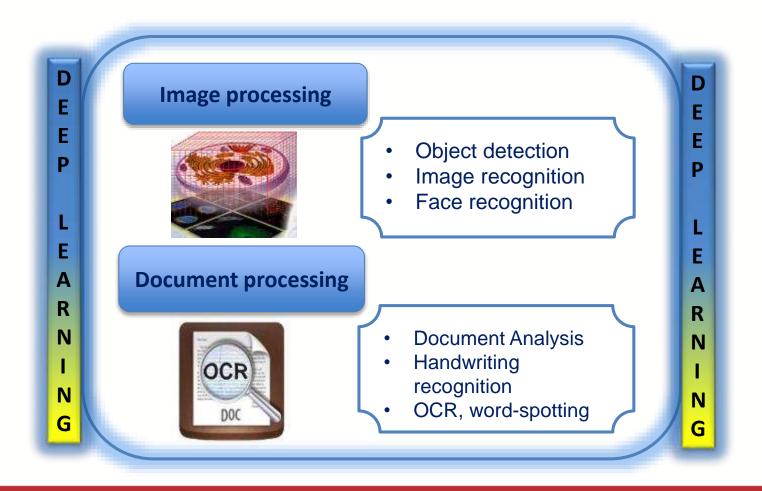




Research activities

DeepVision

Fields : Pattern recognition, Computer vision, Machine learning



Introduction

A huge amount of documents (machine printed, handwritten)

- Preservation
- Storage
- Access to contents



Administrative Documents

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CUC HIGH

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Historical Documents



→ High Cost of manual processing

PayStream Advisors research reveals the average cost of manually processing an invoice can be as high as \$20, versus \$4 for automated invoice

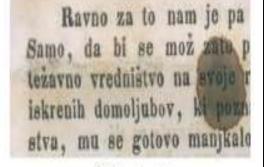
Introduction

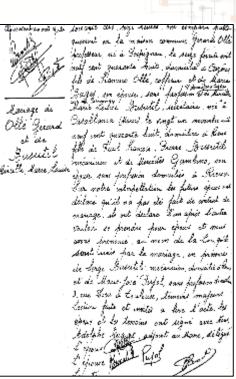
Automatic document processing

- Classification
- Document Enhancement
- Writer/script Identification
- Layout analysis
- Recognition
- Spotting ...

Difficulties

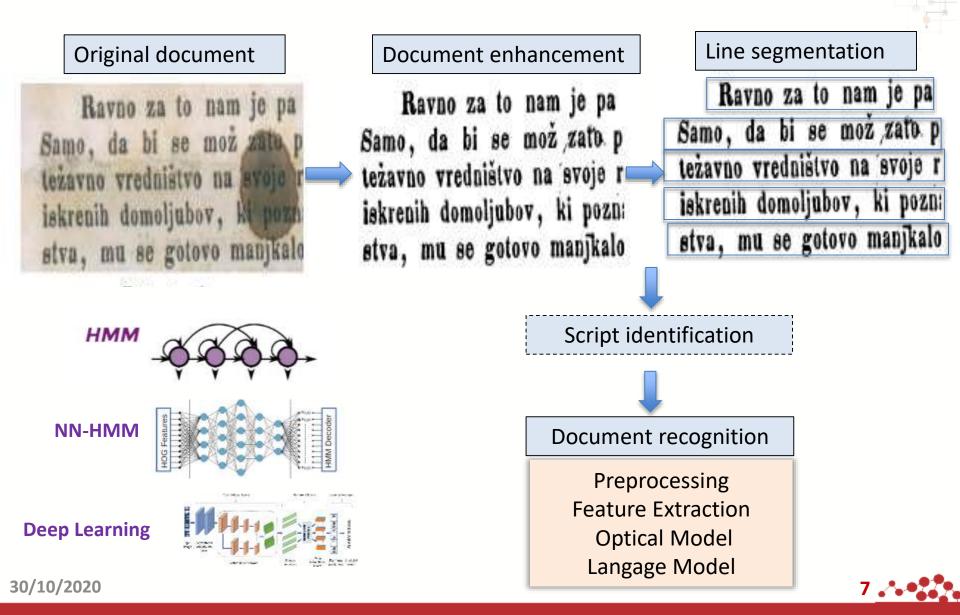
- Unstructured data
- Deformations, noise
- Different handwriting styles
- Segmentation problem





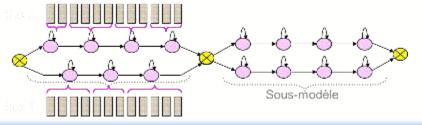
مظفر ضرحام بصحبه رؤوف 75 طرغام وجحب رؤون صغى برخام بججبة رواوف مرناج بمحبة قرودت

Document Recognition process



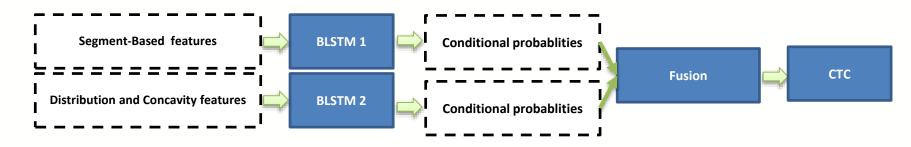
Handwriting recognition before deep Learning

GMM-HMM with carefully chosen features



Y. Kessentini, T. Paquet, A. Benhamadou. Off-Line Handwritten Word Recognition Using Multi-Stream Hidden Markov Models. Pattern recognition Letters (PRL), Vol 30, Issue 1, pp. 60-70, January 2010.

Combination of BLSTMs at different levels



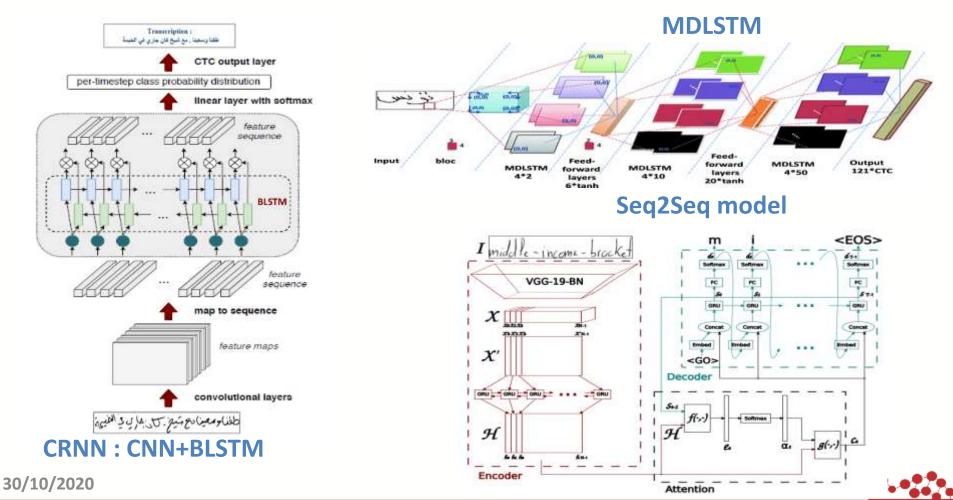
S. Khamekhem Jemni, **Y. Kessentini**, S. Kanoun, Offline Arabic Handwriting Recognition Using BLSTMs Combination. 13th international workshop on document analysis systems (DAS), pp 31-36, Vienna, Austria, 2018.



Deep Learning arrived

Applied directely to the pixel of the raw text line image

○ BLSTM \rightarrow MDLSTM \rightarrow CRNN \rightarrow Seq2Seq ...



HIGH PERFORMANCE WITH DL BUT...

How to recognize degraded documents ?



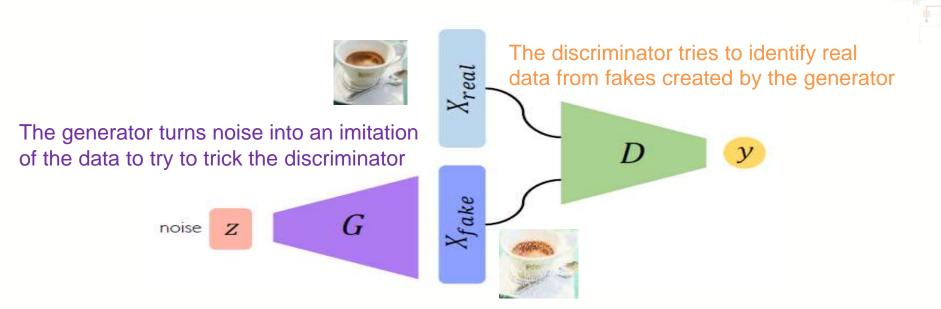
Document Enhancement Use Generative Adversarial Networks (GAN) to restore severely degraded document images. genus includes flex aquifolium, which is native to Europe and known to A new offline handwritten database for the Spanish la-Americans as Christmas holly.) The trees in Ilea were like kids who spend full Spanish sentences, has recently been developed: 1 recess sprawled out on a bench. While Schefflera was sprinting upslope, flex was just sitting there, more or less inert. (which stands for Spanish Restricted-domain Task of an words obligations an NEV Stilliam Pailla were two main reasons for creating this corpus. First Any species (or group of species) that can't cope with some variation do not contain Spanish sentences; even though Spanish pet and thalk assording by wait in temporatures is not a species (or group) whose fate we need be language Another important reason was to create a concerned about right now, because it no longer exists. Everywhere on the surface of the earth temperatures fluctuate. They fluctuate from day restricted tasks. These tasks are commonly used in prair to night and from season to season. Even in the tropics, where the of linguistic knowledge beyond the lexicon level in the rea splan to be g difference between winter and summer Autoininal, temperatures can vary significantly between the rainy and the seasons. Organisms have developed all torts of ways of team of the these variations. They informate or estivate or migraty way dynamic heat through panting or As the Spartacus database consisted mainly of short aling habe the guranity of writing before triver the man of form which and were to hall any fulary contain long paragraphs, the writers were asked to cop fixed places: dedicated one-line fields in the forms. Ne a our. Honeybees warm themselves conserve it by growing thicks o when thoras. Wood storks cool off by the forms used in the acquisition process. These forms by contracting the muscle ery hot weather, wood storks may defecating on their own excrete on their legs a fren a Over the lifetimy is they form temperature in e a minute.) 4.2 Conticuto in AIPL , on the order of a million years, longer-The approach of unlong interest nanges in climate-come into play. For the promitive existensions of Loscid by last forty million es to so, the earth has been in a general cooling cid [1]. In our approach, the nur phase. It's not or ar why this is so, but one theory has it that the uplift of th as exposed vast expanses of rock to chemical the tracking mode, the cotomore in turn led to a drawdown of carbon dioxide from the weatherb to the optimum tampling phase %. start of this long cooling phase, in the late Eccene, the Fullencing approaches of \$72 and atometers 25.0 firm there was almost no ice on the planet. By around world was a should finishe five a given he Drudfebler- un mind ung in determinent by thirty-five million years ago, global temperatures had declined enough that glaciers began to form on Antarctica. By three million years ago, wegen ber Entfernumt bes Hefferfeners"fich temperatures had dropped to the point that the Arctic, too, froze over, and a permanent ice cap formed. Then, about two and a half etillion years bie und ba eingeschliedien babent schuttag ago, at the start of the Pleistocene epoch, the world entered a period of Taking the natural h Wan muß aber boch nicht mehr . air rive recurring glaciations. Huge ice sheets advanced across the Northern mains the long-life-time man tefe: and unfnidalaidist

M. A. Souibgui, Y. Kessentini, DE-GAN: A Conditional Generative Adversarial Network for Document Enhancement, IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI), September 2020

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Components of GANs



Train GAN jointly via minimax game:

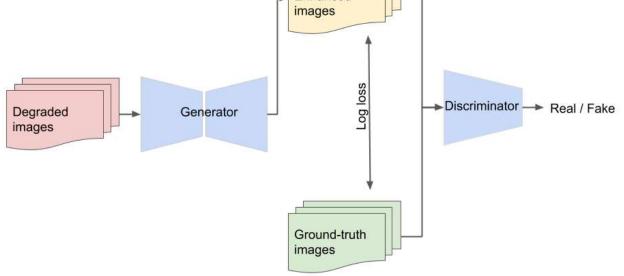
- The discriminator tries to maximize its classification accuracy
- The generator tries to minimize the discriminator's classification accuracy

$$\min_{G} \max_{D} V(D,G) \quad V(D,G) = \mathbb{E}_{x \sim p(x)}[\log D(x)] + \mathbb{E}_{z \sim q(z)}[\log(1 - D(G(z)))]$$

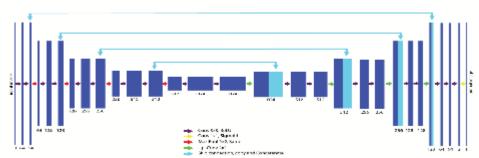
Maximized by D Minimized by G



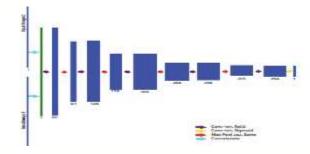
DE-GAN : Document Enhancement GAN







Discriminator





DE-GAN : Document Enhancement

Ravno za to nam je pa Samo, da bi se mož zato p težavno vredništvo na svoje r iskrenih domoljubov, ki pozn stva, mu se gotovo manjkalo Original

Ravno za to nam je pa Samo, da bi se mož zate p težavno vredništvo na svoje i iskrenih domoljubov, ki pozn stva, mu se gotovo manjkale

Niblack [50]

Ravno za to nam je pa Samo, da bi se mož zato p težavno vredništvo na svoje r iskrenih domoljubov, ki pozn stva, mu se gotovo manjkalo

Ground truth

Ravno za to nam je pa Samo, da bi se mož z p težavno vredništvo na iskrenih domoljubov, k stva, mu se gotovo manjkalo Sauvola et al. [51] Ravno za to nam je pa Samo, da bi se mož težavno vredništvo na iskrenih domoljubov, konst stva, mu se gotovo manjkale

Otsu [16]

Ravno za to nam je pa Samo, da bi se mož zato p težavno vredništvo na svoje r iskrenih domoljubov, ki pozn: stva, mu se gotovo manjkalo

DE-GAN



Watermarked images

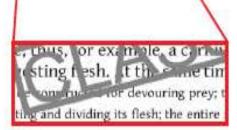
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anversely, an animal with been reast meet mentality be an berbicore. since it is "no means of secting pay." It will have "testit with a fat remain its getad atasis and graces," and a jacs republic of lateral mention. Were any one of these parts to be altered, the functional integrity of the while would be deduced. An antenal the west born with, say, both or, bel organs that were somehow different than its parents" would not be and to survey, let alone goe the bus whole see kind of contain-

In Covier's day, the most prominent proposition of transforment was renker uniferance at the intension of Matural Matery, Jean-Dapinite arrarch Accepting to Lanarch, there was a trees the "power of He"the, attends and also plants often had to cope soling hanges in their ecronomet, they did to by adjusting their habits; they new habits, in rea, produced goysteal anadifications that were then proved down to we offspring, fords that exagint prey in lakes sprind out this toos when my bit the water, and to this way eventually descired write a liter and



Ground truth

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e; thus, for example, a carniv gesting flesh. At the same tim be constructed for devouring prey; t ting and dividing its flesh; the entire

Predicted images

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As Covier Block to point and, he put his fields in matterny; this was what had allowed him to distinguish the losues of a manuscreath from these of an elephont and to receptive as a givet salamander what others took to be a non. At the heart of his understanding of irretory size a section he terrents "correlation of parts." By this he means that the components of an art mai all fit organizer and new operetally designed for its portionals way of the Unit, for energie, a correspondition will have on takentical system without to Senating Besh. At the same time, its jawe will

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in this is it summings in the same starts, see an inclusion of the same starts of the serve organs that were somehow different from its parents' would not be also to survive, let alone give rige to a whole on a band of creature.

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e; thus, tor example, a carniv gesting flesh. At the same tim be constructed for devouring prey; t ting and dividing its flesh; the entire



DE-GAN : Debluring

Blurred images	Ground truth	DE-GAN
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views. In the AIPL, which we discuss encompositive performatives in them, in create new contexts from existing or municative act CA x to an agent B, objects, where each object is broad criteria, temporal properties, constru- in the language. We view this collect 4.2 Contexts in AIPL. The approach of using intensional p is conservative extension of Locid by cid [1]. In our approach, the name	 class objects, we will be able to ex- sions. In the AIPL, which we discue encapsulate performatives in them.¹ create new contexts from existing o- municative act CA x to an agent B, objects, where each object is bound criteria, temporal properties, constra- in the language. We view this collec 4.2 Contexts in AIPL. The approach of using intensional g a conservative extension of Lucid b, cid [1]. In our approach, the name 	 A conservative extension of Lucid b cid [1]. In our approach, the name
the tracking mode, the contrasts 0.1 to the optimizer sampling phase γ_0 . Following approaches of (21) and theories from the e-given sequence is determined by: $\rho (\chi \chi) = \left(\frac{1}{2\pi m_0^2}\right)^2 \exp\left(-\frac{1}{4}\right)^2$	the tracking mode, the estimate $\hat{\tau}$ f to the optimum sampling phase τ_0 Following approaches of [2] and libood function for a given sequen is determined by $\rho(z \tau) = \left(\frac{1}{\pi\sigma_s^2}\right)^K \exp\left(-\frac{1}{\sigma}\right)^K$	the tracking mode, the estimate t t to the optimum sampling phase $\tau_{\rm B}$ Following approaches of [2] and lihoed function for a given sequen is determined by $\rho(\underline{1} \underline{1}) = \left(\frac{1}{R\Theta_{\rm B}^{-1}}\right)^{K} \exp\left(-\frac{1}{\Theta}\right)^{K}$
Eaking the natural legatithm of obtain the key blackbased function $L(x) = \ln \left[\left(-\frac{1}{-x_0} \right)^K \right] - \frac{1}{-x_0}$	Taking the natural logarithm of obtain the log-likelihood function $L(\tau) = \ln\left[\left(\frac{1}{2}\right]^{K}\right] - \frac{1}{2}$	Taking the natural logarithm of obtain the log-likelihood function $\mathcal{L}(U) = \ln \left[\left(-\frac{1}{-1} \right)^{C} \right] = -\frac{1}{-1}$

Source code: https://github.com/dali92002/DE-GAN



HIGH PERFORMANCE WITH DL BUT...

Recognition still depends of linguistic resources

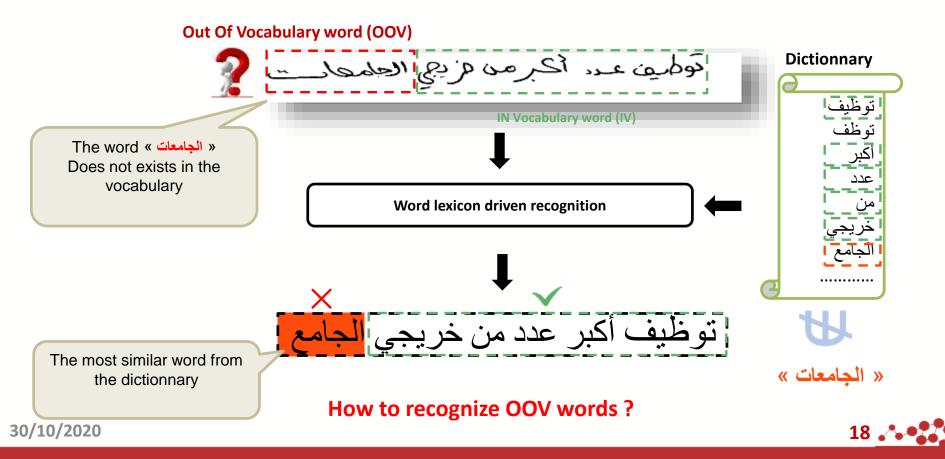
How to handle OOV words ?

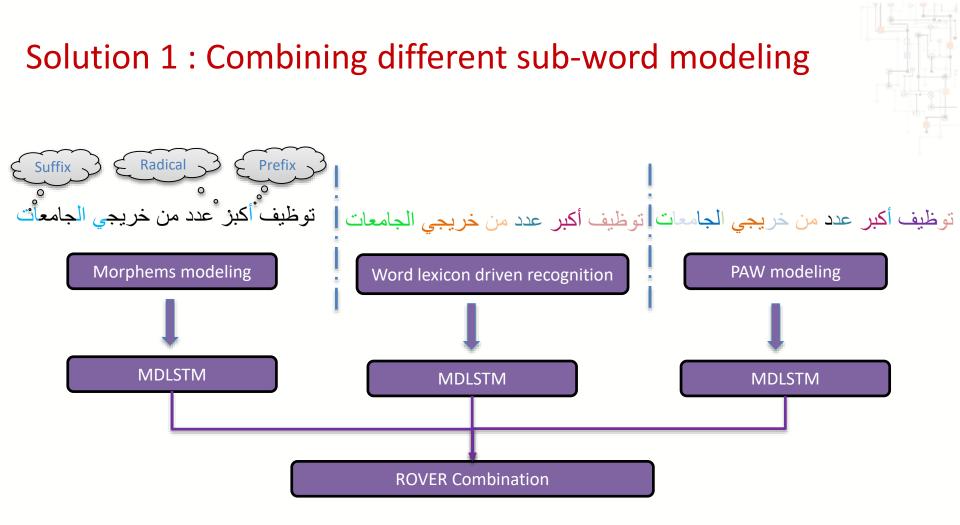


Out-of-vocabulary words

Handwriting recognition systems usually rely on static dictionaries

- Small lexicon: Low coverage rate
- Big lexicon: High computing time + high confusion between words
- Full coverage of these dictionaries is generally not achieved





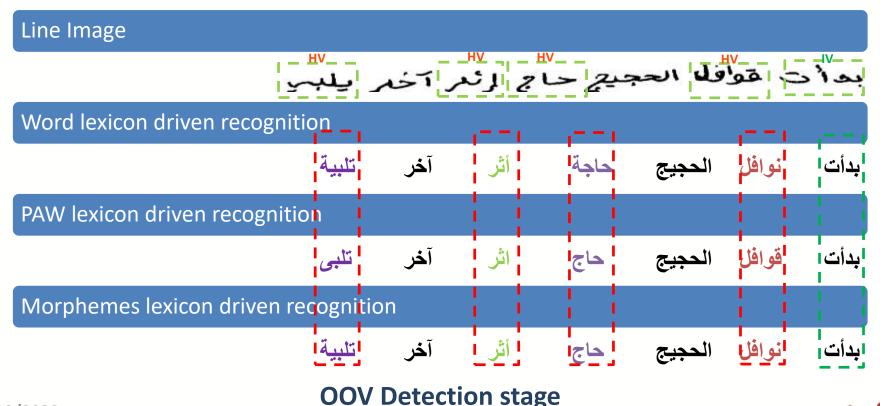
S. Khamekhem Jemni, **Y. Kessentini**, S. Kanoun, Improving Recurrent Neural Networks for Offline Arabic Handwriting Recognition by combining different Language Models, International Journal of Pattern Recognition and Artificial Intelligence. November 2019.



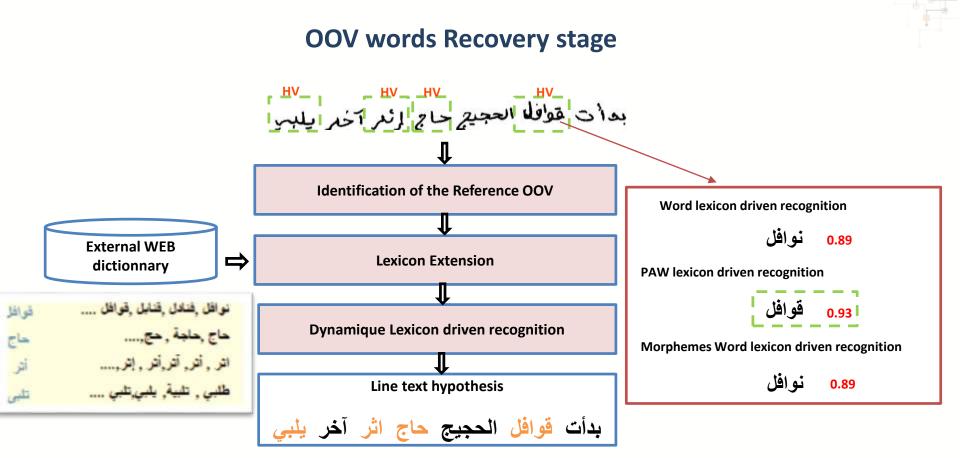
Solution 2 : OOV words detection and recovery using dynamic dictionnaries

Idea:

- Keep the IV words recognized by the word lexicon driven recognition
- Recover OOV word using dynamic lexicons built from large text corpora



Solution 2 : OOV words detection and recovery using dynamic dictionnaries



S. Khamekhem Jemni, Y. Kessentini, S. Kanoun, Out of Vocabulary Word Detection and Recovery in Arabic Handwritten Text Recognition, Pattern Recognition, Vol 93, pp. 507-520, 2019.





Results

- KHATT dataset
- Train : 9475 Test : 2007
- Lexicon : 18933 words, 11,46% OOV

Systems	WER
Hamdani et al. [2]	26.80
BenZeghiba et al. [1]	30.9
BenZeghiba [3]	34.3
Our approach	20.83





HIGH PERFORMANCE WITH DL BUT...

What about cases where you don't have labeled data?



Recognition of ciphered manuscript

Around 1% of documents in archives contain encrypted text:
Diplomatic correspondence, secret societies/religious groups...

DECODE/DECRYPT project: To develop resources & tools for automatic decryption of enciphered documents from early modern times.



Collection

Transcription

Decryption



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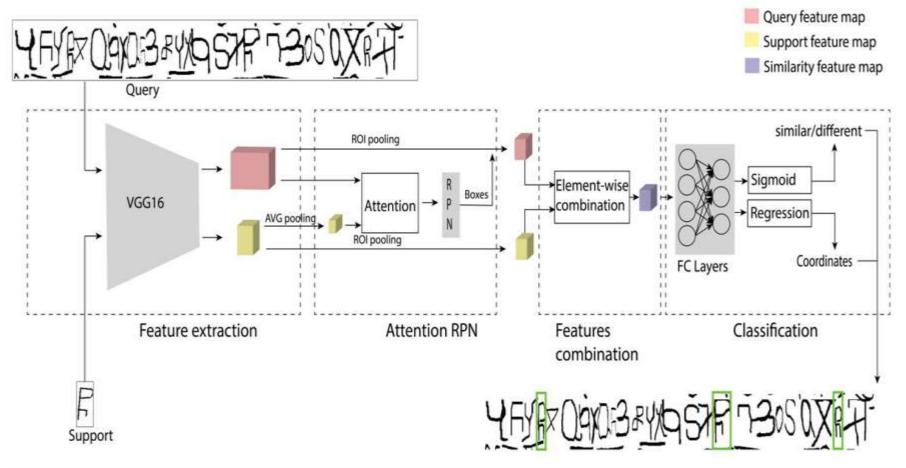
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Problem : Very few (or none) labeled data to train



Few-shot Learning for Historical Ciphered Manuscript Recognition

Symbol detection step

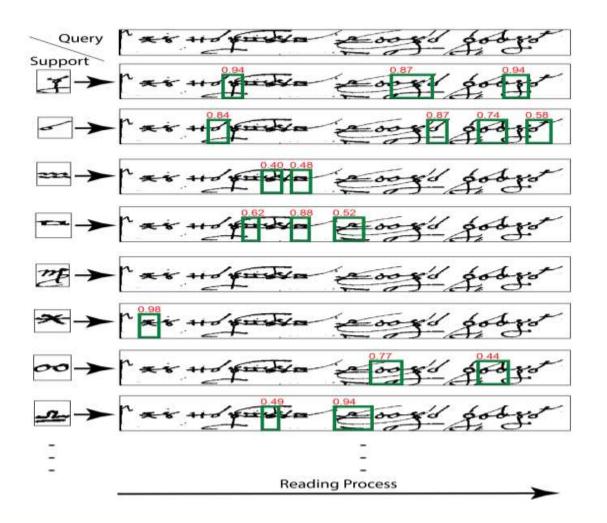


M.A.Souibgui, A.Fornés, Y.Kessentini, C.Tudor. A Few-shot Learning Approach for Historical Encoded Manuscript Recognition, International Conference on Pattern Recognition (ICPR), 2020.

0, 10, 2020

Few-shot Learning for Historical Ciphered Manuscript Recognition

Text recognition step





Few-shot Learning for Historical Ciphered Manuscript Recognition

Train (synthetic): Omniglot	Test (ciphers):	Copiale	Borg
3H@4Rx8rE×9290574+414H4+iXi 4K1≈1K14F6477RPX⊽6074MPF6R7T16-1 G&4u44hEa4bGS5700074SO0077C45447 @a3 a258099094202€ a355-35	pzüjgenôpîmp34zprh	nyálðindjazzzné	нованаводанно 194 на славоданно 194 на славодание вода на осокатово вода орн

	Copiale			Borg		
Method	Training Pages	Shots	SER	Training pages	Shots	SER
LSTMs	25	-	0.11	7	-	0.55
	34	-	0.10	9	-	0.52
	42	-	0.07	11	-	0.45
Few-	2	1	0.10	2	1	0.17
shot		5	0.10		5	0.18



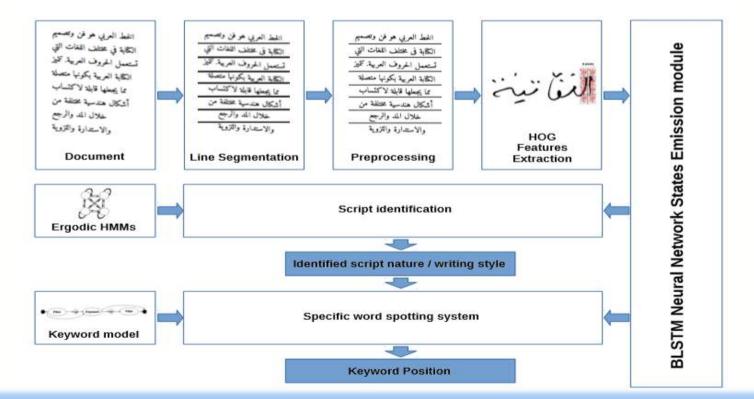
BUT... DO WE NEED TO RECOGNIZE ALL THE DOCUMENT ?



Keyword spotting

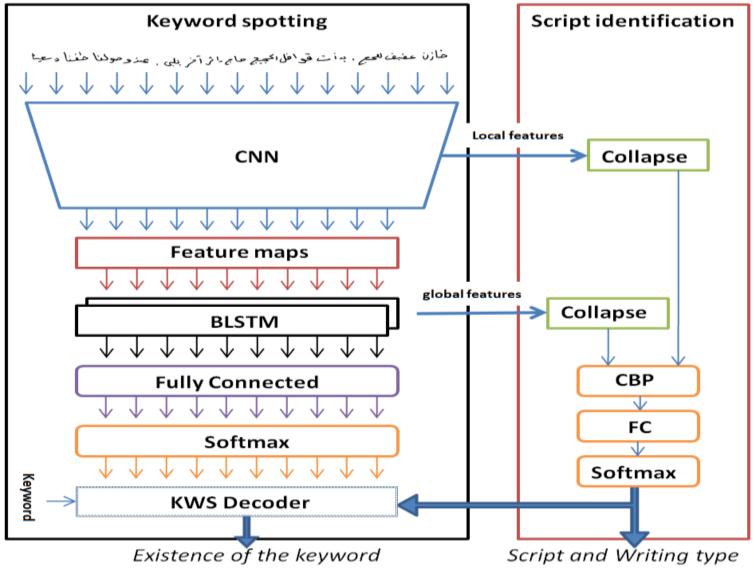
Finding all instances of a query word that exist in a scanned document image, without fully recognizing it.

Document indexing and retrieval, routing, categorization...



A. Cheikhrouhou, Y. Kessentini, S. Kanoun, Hybrid HMM/BLSTM system for multi-script keyword spotting in printed and handwritten documents with identification stage, Neural Computing and Applications, vol. 32, pp. 9201–9215, 2020.

Multi-task learning



30/10/202_

30

Results

Script identification results (Multi-task Learning)

Script	Handwritten French	Handwritten Arabic	Printed Arabic
Handwritten French	100%	0%	0%
Handwritten Arabic	0%	99.9%	0.1%
Printed Arabic	0%	0.11%	99.89%

Keyword spotting results (100 keywords MAP)

System	Handwritten French	Handwritten Arabic	Printed Arabic
Multi-Task	89%	92.87%	98.29%
BLSTM-HMM	70.12%	84.76%	82.15%
НММ	51.9%	49.1%	61.8%



BUT... IS RECOGNITION ENOUGH?



Recognition \rightarrow Understanding

READ project

3.,

Information Extraction: Transcription + Semantic Recognition (NER)

Death, birth and marriage records

Files		Itad- La trois faminer mile weef cont esisante des, querze haves timber, and song and protoprominet an ha maiser commune, hogen, Jorman, Higett	Nom Epoux	Prénom Epoux Roger German
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INFORMATION EPOUX

Conclusion

 Whenever I say that I am a researcher in Document Analysis & Recognition, people say :

I thought it was a solved problem !

Real data, realistic problem

2022	·			
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Real data, real problem

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Very difficult to reach, even for industrial solution providers



The future

- Full-page Document recognition
- There will be a new approach to OCR
 - Seq2Seq, Transformers, Graph Neural Networks...
- Labeled data is an important limitation
 - Data generation, DomainAdaptation, Few/zero-shotLearning...
- Neuro-Symbolic AI
 - Represents the causal and compositional processes behind perceptual observations
 The goal is to create explainable AI systems that can tackle more complex tasks while increasing accuracy, learning from fewer examples and using less data.





The Internationl Conference on Intelligent Systems and Pattern Rocognition

16-18 October Hammamet (Tunisia)

Thank you!

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