ICDAR2013 Competition on Multi-font and Multi-size Digitally Represented Arabic Text

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Abstract—**This paper describes the Arabic Recognition Competition: Multi-font Multi-size Digitally Represented Text held in the context of the 12th International Conference on Document Analysis and Recognition (ICDAR'2013), during August 25-28, 2013, Washington DC, United States of America. This competition has used the freely available Arabic Printed Text Image (APTI) database. A first edition took place in ICDAR'2011. In this edition, four groups with six systems are participating in the competition. The systems are compared using the recognition rates at character and word levels. The systems were tested in a blind manner using set 6 of APTI database. A short description of the participating groups, their systems, the experimental setup, and the observed results are presented.**

Keywords-**APTI Database; Arabic Text; Ultra-Low Resolution; OCR System; Competition;**

I. INTRODUCTION

It has become a tradition to organize competitions at the International Conference on Document Analysis and Recognition (ICDAR)[1][2][3] and the International Conference on Frontiers in Handwriting Recognition (ICFHR)[4][5]. These competitions allow to improve the classification techniques and to compare and evaluate different techniques and systems [1], [2], [3], [4], [5]. In the same way, the growing availability of benchmarking databases [6], [7], [8], [9], [10] have contributed to systematic comparisons of various strategies and to achieve considerable improvements.

These competitions are dedicated to handwritten Arabic text, handwriting segmentation, digit recognition, historic document, etc. But most of then use images at high resolution. In 2003 and 2011, only two competitions are organized in the field of text recognition in scene images and use images at low-resolution for non-Arabic text [11], [12]. For this reason, we are interested in the recognition of Arabic text at ultra-low resolution to motivate researchers to work in this interesting domain. The scientific objectives of this competition are to measure the impact of font/size on the recognition performances. The protocols are defined to evaluate the capacity of recognition systems to handle different sizes and fonts using ultra-low resolution images in the aim to look for a robust approach to screen based OCR. The main difficulty is probably in the multi-font context as differences between fonts are rather important for Arabic text. To the best of our knowledge, the only free database for Arabic printed text is the Arabic Printed Text Image database (APTI) [6]. The most interesting characteristics of APTI are: very large set of images for significant benchmarking ($>$ 45 millions images), large lexicon, multi-font, multi-size and single word images. Potentially less difficult than handwritten Arabic text recognition, APTI remains challenging due to the variabilities induced by the different fonts and sizes that, in some cases, change drastically the distributions of observed features. APTI is typically related to OCR and "screen-based" OCR inputs where the user grab and crop a part of the computer screen.

The evaluation has been organized using a blind procedure. The testing data of the evaluation is composed of an unpublished set (so called *set 6* of APTI) which is kept secret for evaluation purposes. The participants were able to train and tune their systems using the public parts of APTI. Then, they were asked to send an executable version of their recognizer to the organizers who, in turn, arranged to run the systems against an unseen set of data. The first competition on multi-font and multi-size digitally represented Arabic text was based on set 6 of the APTI database, and the results were presented at the International Conference on Document Analysis and Recognition (ICDAR) 2011 [4]. Two groups submitted three systems to this competition. Compared to

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[1]http://www.cvc.uab.es/icdar2009/competitions.html
[2]http://www.icdar2011.org/EN/column/column26.shtml
[3]http://www.icdar2013.org/program/competitions
[4]http://www.icfhr2012.uniba.it/index.php
[5]http://www.isical.ac.in/~icfhr2010/index.html

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Figure 1. Fonts used to generate the APTI database: (A) Andalus, (B) Arabic Transparent, (C) AdvertisingBold, (D) Diwani Letter, (E) DecoType Thuluth, (F) Simplified Arabic, (G) Tahoma, (H) Traditional Arabic, (I) DecoType Naskh, (J) M Unicode Sara

the first edition, we have tested systems with more fonts and in different contexts in this second competition.

The paper is organized as follows. Section 2 summarizes the main characteristics of APTI database. Section 3 is dedicated to the competition protocols. In section 4, we present the participating systems. Results are discussed in Section 5 and are followed by conclusions.

II. THE APTI DATABASE

The APTI database was developed to promote the research and development of Arabic printed word recognition systems. Available from July 2009, APTI is freely distributed to the scientific community for benchmarking purposes [6]. At the time of writing this paper, 33 research groups have started using it.

The APTI database was created in ultra-low resolution "72 dot/inch" with a lexicon of 113,284 different Arabic words and 10 fonts presented in Figure 1. These fonts have been selected to cover different complexity of shapes of Arabic printed characters. Different font sizes are also used in APTI: 6, 7, 8, 9, 10, 12, 14, 16, 18 and 24 points. We also used 4 different styles namely plain, italic, bold and combination of italic and bold. The combination of fonts, styles and sizes guaranties a wide variability of images in the database. The total number of word images is above 45 million. Each word image in the APTI database is in grey level and fully described using an XML file containing ground truth information about the sequence of characters as well as information about its generation. All Arabic letters have a balanced distribution throughout the sets composing the database. Table I shows the total quantity of word images, Piece of Arabic Words (PAWs) and characters in APTI.

Table I
QUANTITY OF WORDS, PAWS AND CHARACTERS IN APTI

	Nber of Words	Nber of PAWs	Nber of Characters
	113,284	274,833	648,280
	*10 Fonts * 10 Font Sizes * 4 Font Styles		
Total	45,313,600	109,933,200	259,312,000

The database is divided into six comparable sets to allow for flexibility in the composition of development and evaluation partitions. For more details about APTI, we refer to [6] and [13].

III. THE COMPETITION

We invited groups participating to this context to adapt their system to the APTI database and to send us executable programs of their systems.

The evaluation is reported as word and character recognition rates. In this edition, we use the writing style: **Plain** and the font-sizes (**6**, **8**, **10**, **12**, **18** and **24**) used in the first edition and we proposed 4 protocols:

1) Reference APTI Protocol for Competition: Ref. APTIPC. This protocol is the same one proposed in the first edition of the competition. To participate to this protocol, participants should submit six systems (one for each Size) or one system using the parameter size. *Font:* **Arabic Transparent**

2) First APTI Protocol for Competition: 1st APTIPC. This protocol uses the same font used in the reference protocol but independently to the size. Participants should submit one multi-size system for this protocol. *Font:* **Arabic Transparent**

3) Second APTI Protocol for Competition: 2nd APTIPC. This protocol uses the ligatured font DecoType Naskh independently to the size. Participants should submit one multi-size system for this protocol. *Font:* **DecoType Naskh**

4) Third APTI Protocol for Competition: 3rd APTIPC. This protocol uses All APTI fonts independently to the size. Participants in this protocol should submit one multi-font and multi-size system. *Fonts:* **Andalus**, **Arabic Transparent**, **Advertising-Bold**, **Diwani Letter**, **DecoType Thuluth**, **Simplified Arabic**, **Tahoma**, **Traditional Aatbic**, **DecoType Naskh** and **M Unicode Sara**

IV. PARTICIPATING SYSTEMS

This section gives a short description of the submitted systems to the competition.

A. Siemens System

The Siemens System is submitted by Marc-Peter Schambach, Joerg Rottland and Sheikh Faisal Rashid, from Siemens AG and Image Understanding and Pattern Recognition (IUPR), University of Kaiserslautern, Germany. The

system is based on recurrent neural networks described by Alex Graves in [14], [15]. It is a multi-layer neural network, which basically transforms a two-dimensional pixel plane into a sequence of class probabilities. It does so by sub-sampling the input pixel planes in each layer and finally collapsing the final plane in y-direction, getting away with a sequence in x-direction. Each layer is recurrent getting its input not only from the input pixel, but also from the neighboring cells within the layer. Cells are long short-term memory (LSTM) cells containing rich structure with input, output and forget gates. The network topology consists of three hidden layers, with 2, 10 and 50 cells each. Sub-sampling layers have dimension 1×2 or 2×3 (depending on image size) with 6 and 20 cells. A separate network has been trained for each font size of the reference task. For the multi-size tasks 1 to 3, images have been scaled to common heights for training. Depending on the test image size, one of multiple trained networks is chosen for recognition.

B. UPV-BHMM Systems

The UPV-BHMM systems are submitted by Ihab Alkhoury, Adrià Giménez, Jesús Andrés-Ferrer and Alfons Juan, from the Universitat Politècnica de València (UPV), València, Spain.

The UPV-BHMM system is built from character-based windowed BHMMs (Bernoulli HMMs) which are adequately concatenated so as to produce a different wordlevel windowed BHMM for each word to be recognized [16], [17]. Given a text image of an unknown word, it is first transformed into a sequence of binary feature vectors by applying a sliding window at each horizontal position. The width of the sliding window is known to have a strong effect on the system ability to capture local image distortions. However, local image distortions, and vertical distortions in particular, might not be properly modeled when the sliding window is applied at a constant vertical position of the image. To overcome this limitation, we applied the repositioning (translating) of the sliding window before its actual application. More precisely, the sliding window is repositioned so as to align its center with its mass center. More details on this idea is described in [18]. Three variants of the UPV-BHMM system have been submitted for the first three protocols: Ref. APTIPC, 1st APTIPC, and 2nd APTIPC.

C. SID Systems

The SID System is submitted by Oussama Zayene, Najoua Essoukri Ben Amara and Sameh Touj members in the Signal, Image and Document Team. This team is part of the SAGE UR (Systèmes Avancés en Génie Electrique) at the National Engineering School of Sousse, Tunisia. SID-System is based on Hidden Markov Models using the HTK toolkit. It is an open vocabulary recognition system. It does not require segmentation.

The proposed system involves two main stages: training and recognition. Preprocessing and features extractions steps are common for both phases. From each word image, they extract a set of characteristics using the sliding window technique. In this case, they use 6 pixels width and an overlap between two successive windows of 1 pixel. Each window is further divided vertically into 9 cells. Each word image is then transformed into a matrix of values where the number of lines corresponds to the number of analysis windows, and the number of columns is equal to the number of feature coefficients in each feature vector. During the training phase, a right-left HMMs corresponding to the known sequence of characters are prepared for each word, associated with the features file. Once the HMM parameters are initialized, an embedded iterative training of character models is performed using a Baum-Welch procedure. The recognition is done using the Viterbi algorithm applied to an ergodic HMM defined by the set of all character models. More details about this system are presented in [19].

D. THOCR Systems

THOCR systems are submitted by Zhiwei Jiang, Xiaoqing Ding, Changsong Liu and Liangrui Peng from Center of Intelligent Image and Document Processing (CIDP) Department of Electronic Engineering at Tsinghua University in China.

Hidden Markov Model is the core technique of all three systems. And HTK (Hidden Markov Model Toolkit) is used for the training, decoding and rescoring process.

These three systems follow the classic pre-processing procedure of HMM-based systems. At first, normalized image in 120 pixels height is sequenced for frames by an 8-pixel-width sliding window with 1 pixel step. Then, 28-dimension feature is extracted frame by frame. Two third of features are statistical one and the rest are structural one. At the same time, the position of upper and lower baseline are also used to divide image into different zones for statistical purpose. As to each feature extracted, an additional 28-dimension differential feature is calculated through previous and next neighbor ones and adhered to the end of original 28-dimension feature. So 56-dimension feature is extracted in all THOCR systems.

THOCR 1 system is a simple HMM-based one. The usual Embedded Baum-Welch algorithm and Viterbi algorithm are used for training and decoding separately. All 128 Arabic letters and two kinds of space are illustrated by 67 models. Similar letters will share one model because model can be trained better with more sample data.

THOCR 2 system nearly includes all procedures of THOCR 1. But a 4-gram language model, which is trained with the ground truth of all training sets available in APTI, is used in THOCR 2. It rescores the path of state transition after decoding finished.

System/Size		6	8	10	12	18	24	Mean RR
SID	WRR	94.30	96.23	98.18	98.78	96.60	97.41	96.92
	CRR	99.66	99.95	99.96	99.91	99.97	99.99	99.91
UPV-BHMM	WRR	97.25	99.67	99.78	99.88	99.90	99.90	99.40
	CRR	99.48	99.93	99.96	99.96	99.96	99.96	99.88
THOCR1	WRR	75.97	88.06	89.08	87.73	88.97	91.77	86.93
	CRR	97.90	99.13	98.93	98.93	98.92	98.95	98.79
THOCR2	WRR	89.47	95.83	94.80	92.48	94.57	95.03	93.70
	CRR	98.28	99.46	99.15	99.07	99.13	99.19	99.05
Siemens	WRR	**99.87**	**99.92**	**99.95**	**99.94**	**99.96**	**99.97**	**99.94**
	CRR	**99.98**	**99.99**	**99.99**	**99.99**	**100**	**100**	**99.99**

Font/Size		6	8	10	12	18	24	Mean RR
SID	WRR	93.80	97.28	96.84	96.54	96.14	96.70	96.22
	CRR	99.47	99.78	99.82	99.81	99.79	99.83	99.75
UPV-BHMM	WRR	96.71	99.50	99.78	99.90	99.90	99.92	99.29
	CRR	99.41	99.94	99.97	99.99	99.98	99.98	99.88
THOCR1	WRR	40.68	66.69	78.86	85.46	86.74	86.67	74.18
	CRR	93.29	98.40	99.01	99.25	99.28	99.29	98.09
THOCR2	WRR	67.40	86.85	93.37	94.64	95.37	95.50	88.86
	CRR	94.99	98.65	99.28	99.46	99.54	99.57	98.58
Siemens	WRR	**99.45**	**99.86**	**99.92**	**99.85**	**99.96**	**99.88**	**99.82**
	CRR	**99.93**	**99.98**	**99.99**	**99.98**	**100**	**99.98**	**99.98**

Font/Size		6	8	10	12	18	24	Mean RR
SID	WRR	64.12	76.99	80.61	81.40	86.88	86.81	79.47
	CRR	94.05	96.65	97.36	97.77	98.46	98.52	97.14
UPV-BHMM	WRR	85.57	92.15	93.23	93.53	93.55	93.81	91.97
	CRR	97.16	98.47	98.71	98.77	98.76	98.81	98.45
THOCR1	WRR	5.42	44.93	57.09	58.33	60.14	58.49	47.40
	CRR	72.40	92.49	94.65	94.92	95.11	95.04	90.77
THOCR2	WRR	17.00	61.84	69.89	71.09	72.64	72.07	60.76
	CRR	75.99	92.65	94.62	94.85	95.24	95.02	91.40
Siemens	WRR	**98.82**	**99.20**	**99.24**	**99.72**	**99.75**	**99.37**	**99.35**
	CRR	**99.83**	**99.87**	**99.90**	**99.96**	**99.97**	**99.93**	**99.91**

Both THOCR 1 and THOCR 2 are designed for single-font Arabic character recognition originally. So they will be evaluated in the reference protocol, protocol 1 and 2.

THOCR 3 system is extremely different from the two ones above, because it contains two HMMs inside for multi-font Arabic character recognition in Protocol 3 specially. Through analyzing the character recognition performance confusion matrix of 10-font samples, we cluster 10 fonts into 6 ones and train 6 corresponding HMM-based font models at first. Before doing character recognition, THOCR 3 system will identify the font of current sample by font HMM. Then, the system works the same as THOCR 2 using character HMM with a certain font.

Moreover, the font recognition is also accomplished with the same 56-dimension feature, but the model is trained by font-based ground truth instead.

V. TESTS AND RECOGNITION RESULTS

All systems have been tested using the *set 6* (18,866 single word images) of APTI database in different fonts and sizes. All participants sent us a running version of their recognition systems. The systems can be categorised in two groups depending on the operating system: three systems are developed under Linux (UPV-BHMM, Siemens and SID) and three system under Microsoft Windows environment (THOCR 1, THOCR 2 and THOCR 3). For each test the best result is marked in bold.

Table II presents all system results of the reference APTI protocol (Ref. APTIPC). This test is mono-font and mono-size. The test images presented to the systems are the one rendered using the font "Arabic Transparent", plain and sizes 6, 8, 10, 12, 18 and 24. The comparison of the systems based on the results shows 4 systems with a word recognition rate better than 93 %. Siemens systems show the best results with an average of 99.94 % and 99.99 % respectively for the word and character recognition rates. Additionally, they are also the faster ones compared to other competition systems.

Table III presents all system results of the first APTI protocol (1st APTIPC). This test is mono-font and multi-size. Only one system should be submitted for this protocol. The test images are the same used for the reference protocol. For all systems, we obtained good results in character

recognition. The best system has a mean word recognition rate of 0.53 % higher than the second-best system, and 3.6 % than the third-best system.

The second APTI protocol (2nd APTIPC) is also mono font and mono size. Table IV presents all system results of this test. The images presented to the systems are the one rendered using the font "DecoType Naskh", plain and sizes 6, 8, 10, 12, 18 and 24. For most of the systems, the results are slightly worse for the word recognition compared to the previous protocols. This can be explained by the complex writing morphology of this font rich in ligatures and overlaps between characters. Siemens systems show the best results with an average of 99.35 % for the word recognition rate and 99.91 % for the character recognition rate.

Tables V and VI presents respectively Siemens and THOCR 3 systems results of the third APTI protocol (3rd APTIPC) for competition. Other participants do not participate to this protocol. This third test is multi-font and multi-size. Both systems show good character recognition rates. However, Siemens system is the best one with an average of 99.07 % for the word recognition rate and 99.84 % for the character recognition rate.

VI. CONCLUSIONS

The objective of the second competition for Arabic text recognition was to evaluate and compare different systems and approaches in the mono and multi-font contexts. Four groups presenting six systems have participated at IC-DAR2013 competition on multi-font and multi-size digitally represented Arabic text. The Siemens system is the winner in all protocols of this second edition.

Table V
3^{rd}APTIPC - Siemens System results

Font/Size		6	8	10	12	18	24	**Mean RR**
Advertising Bold	WRR	99.86	99.96	99.97	99.97	99.96	99.95	**99.95**
	CRR	99.98	100	100	100	100	99.99	**99.99**
Andalus	WRR	98.93	99.88	99.92	99.91	99.92	99.76	**99.72**
	CRR	99.85	99.98	99.99	99.99	99.99	99.96	**99.96**
Arabic Transparent	WRR	99.57	99.92	99.99	99.97	99.99	99.94	**99.90**
	CRR	99.95	99.99	100	100	100	99.99	**99.99**
M Unicode Sara	WRR	95.70	97.63	97.66	97.75	97.82	97.68	**97.71**
	CRR	99.28	99.59	99.60	99.61	99.62	99.60	**99.60**
Tahoma	WRR	99.65	99.94	99.97	99.98	99.97	99.96	**99.91**
	CRR	99.96	99.99	100	100	100	99.99	**99.99**
Simplified Arabic	WRR	99.30	99.90	99.94	99.95	99.95	99.85	**99.82**
	CRR	99.90	99.99	99.99	99.99	99.99	99.99	**99.98**
Traditional Arabic	WRR	96.16	99.33	99.77	99.68	99.78	99.70	**99.07**
	CRR	99.51	99.92	99.97	99.96	99.97	99.95	**99.88**
DecoType Naskh	WRR	97.17	99.25	99.16	99.18	99.15	98.83	**98.79**
	CRR	99.61	99.89	99.41	99.50	99.87	99.83	**99.69**
DecoType Thuluth	WRR	96.35	99.24	99.92	99.92	99.44	99.27	**99.02**
	CRR	99.49	99.90	99.92	99.94	99.91	99.90	**99.84**
Diwani Letter	WRR	91.77	97.60	98.28	98.41	98.06	96.68	**96.80**
	CRR	98.70	99.64	99.72	99.74	99.68	99.44	**99.49**
Mean RR	WRR	97.64	99.27	99.46	99.47	99.40	99.16	**99.07**
	CRR	99.65	99.89	99.86	99.87	99.90	99.87	**99.84**

Table VI
3^{rd}APTIPC - THOCR 3 System results

Font/Size		6	8	10	12	18	24	Mean RR
Advertising Bold	WRR	86.05	87.99	88.55	88.42	87.14	85.90	87.34
	CRR	97.54	97.98	98.09	98.06	97.83	97.70	97.87
Andalus	WRR	71.70	91.10	94.28	95.88	97.09	96.61	91.11
	CRR	90.51	98.11	99.00	99.42	99.67	99.54	97.71
Arabic Transparent	WRR	47.18	76.56	92.71	94.24	93.99	94.40	83.18
	CRR	79.48	93.12	98.98	99.32	99.22	99.27	94.90
M Unicode Sara	WRR	38.57	55.89	76.51	77.97	80.66	80.04	74.21
	CRR	82.86	91.21	97.12	97.52	97.87	97.70	96.28
Tahoma	WRR	61.26	85.46	85.78	86.34	84.21	82.56	80.94
	CRR	92.84	98.52	98.52	98.66	98.78	97.81	97.52
Simplified Arabic	WRR	42.61	82.76	91.69	91.12	91.62	91.13	81.82
	CRR	82.76	95.45	98.74	98.64	98.60	98.49	95.45
Traditional Arabic	WRR	10.39	34.98	53.57	57.29	68.01	69.46	48.95
	CRR	67.06	80.59	88.77	91.01	93.83	94.42	85.95
DecoType Naskh	WRR	14.75	38.19	47.49	47.68	52.09	50.96	41.86
	CRR	69.65	82.69	86.96	88.03	89.34	89.16	84.31
DecoType Thuluth	WRR	12.44	26.97	39.45	48.22	54.11	53.06	39.04
	CRR	69.26	78.81	83.97	87.71	90.06	89.55	83.23
Diwani Letter	WRR	5.21	19.52	28.30	31.45	92.74	33.20	35.07
	CRR	53.86	74.70	80.02	82.26	99.17	83.31	78.89
Mean RR	WRR	40.75	62.00	69.83	71.86	80.11	73.73	64.82
	CRR	79.42	89.71	93.02	94.06	96.42	94.70	90.65

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