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COLOUR PLATES

Front cover:

Kim Jungyn (Kisan), "[Band of musicians] playing", the drawing No. 24 from the album preserved in the collection of the St. Petersburg Branch of the Institute of Oriental Studies (call number B-35), China ink and water-colours, the second half of the 19th century, 14.0 × 21.5 cm.

Back cover:

- Plate 1. Kim Jungyn (Kisan), "That is how officials (= eunuchs?) in charge of security and palace's tidiness look like (?)", the drawing No. 37 from the same album, China ink and water-colours, 14.0 × 21.5 cm.
- Plate 2. Kim Jungyn (Kisan), "This is how the officials clad in formal red garments and hats decorated with gold (for a morning audience) look like", the drawing No. 54 from the same album, China ink and water-colours, 14.0 × 21.5 cm.
- Plate 3. Kim Jungyn (Kisan), "The uniform of the official in charge of the sovereign's safety and responsible for passing his orders", the drawing No. 28 from the same album, China ink and water-colours, 14.0 × 21.5 cm.
- Plate 4. Kim Jungyn (Kisan), "Officials attached to the sovereign", the drawing No. 35 from the same album, China ink and water-colours, 14.0 × 21.5 cm.

RUSSIAN ACADEMY OF SCIENCES THE INSTITUTE OF ORIENTAL STUDIES ST.PETERSBURG BRANCH



Manuscripta Orientalia

International Journal for Oriental Manuscript Research

Vol. 2 No. 3 September 1996



75ESA St. Petersburg-Helsinki

ORIENTAL MANUSCRIPTS AND NEW INFORMATION TECHNOLOGIES

E. A. Rezvan, N. S. Kondybaev

NEW TOOL FOR ANALYSIS OF HANDWRITTEN SCRIPT*

In the end of 1980th a group of scholars from St. Petersburg Branch of the Institute of Oriental Studies (Russian Academy of Sciences) started realization of the "Asiatic Museum" project [1]. The goal was to produce the database on the manuscripts preserved in the collection of the St. Petersburg Branch of the Institute as a step towards the creation of the hierarchy of expert systems on different kinds of Oriental manuscripts.

The data-base had to present the three level computer description of all manuscripts from the collection. The differences between the levels were connected with the depth of description and degree of access freedom to the information via network. The first level represented the basic information on a manuscript which is nearly common to all the national traditions (see *Table 1*). The second level had to be enriched by image files of incipit and some other elements of the manuscript, as well as by the block of codicological information. The questions that are posed by a scholar to the manuscripts within the national tradition (see *Table 2*). On the second and the third level national languages for description were expected to be used [2].

The third level of computer description (see *Table 3*) had to deal with the group of manuscripts within the national tradition (for example, Qur'an or Bible manuscripts within the Arabic and Hebrew traditions correspondingly) or with certain elements of a manuscript (for example, paper, binding, script, etc.) [3].

It was decided to start the creation of "Asiatic Museum" data-base with ten thousand Arabic and ten thousand Tibetan manuscripts. The Qur'anic manuscripts had been taken as the pilot group of MSS for the realization of the third level description [4]. One of the main problems in the modern Qur'ānic studies is connected with the estrangement of the analysis of Muslim tradition from the description and study of the Qur'ānic manuscripts [5]. In this connection the creation the data-base on Qur'ānic manuscripts written in the variety of angular scripts commonly described as Kufic and early cursive variant of the Arabic script like *hijāzī* or *mā'il* seems to be the only way to reconstruct the real picture of the early text history of the Qur'ān. Such a data-base would be not only a simple computer catalogue, but a highly important research tool as well. It could be viewed as the first step on the way to the realization of the expert system on Qur'ānic manuscripts (see Table 4).

Owing to unique information gathered by German and French scholars [6], we know that even when one deals with the scripts looked very much alike, it is only necessary to trace the shape of final $q\bar{a}f$ or $m\bar{n}m$ to distinguish the hands. It was proposed also to add to the script description the analysis of the shape of *alif* and several ligatures. In this connection new possibilities have been opened with the automatization of graphic recognition. Scanning may be used for the purpose of automatic or semi-automatic comparison of the letter shapes and various fragments of illustration.

The approach described below is connected with an attempt to create the software for this purpose. Since the software proved to have been fruitful tool for the shape analysis of nearly any script (for instance, Norwegian runes), we decided to present here the basic mathematical description of the approach. We hope that this would be of some use for our colleagues who cope, as far as we know, with close tasks in different research centers.

* * *

Selection of the separating parameters for automatic classification of images is a significant problem of recognizing the image. These parameters should provide an essential symbol information about object being displayed as an image. The set of parameters depends on selection of an image representation model. These models are built with

^{*} The realization of the project became possible only because of the energy of Professor Joseph Bell and financial support of the Bergen University and the Norwegian Center for the Computing in Humanities (special thanks to Dr Espen S. Ore), as well as due to the grant of the Secretariat for Cultural Exchange Programmes (KAS) of the Research Council of Norway.

the help of the analysis of object's structure and are based on such parameters as contrast, brightness, shape and texture. The most important parameter for a symbolic image is its shape characteristics. Therefore it is these characteristics that are used in many algorithms of Optical Character Recognition (OCR) [7]. The analysis of object's structure is a matter of some difficulty and takes much of CPU time because of different styles of symbol writing.

One of the goals of the present paper is to define the object-classification parameters which describe an object as a whole. These parameters can be obtained using the maximum entropy approach. There are two factors contributing to this approach:

Statistical model of symbolic image

A symbolic image is normally considered within a limited domain of plane referred to as symbol perimeter (SP). Assume that a symbol picture is scaled to the dimensions corresponding to SP and appropriately processed prior to recognition.

Now we will consider a symbol picture having distortion of structure's elements caused only by different style of writing.

SP dimensions are $l_x \times l_y$.

Let us define a function for SP:

$$C(x_i, y_i) = \text{Abs}(x_0 - x_i)^* \text{Abs}(y_0 - y_i)$$
 (1)

where x_i , y_i are current coordinates; x_0 , y_0 are coordinates of SP's center.

This function is a weighing one having the following properties:

1)
$$C(x_0, y_0) = C(x_0, y_i) = C(x_i, y_0) = 0$$
.

2) Points of one and the same weight (C(x, y) = Const) belongs to a hyperbolic curve.

3)
$$\int_{0}^{l_{x}/2} \int_{0}^{l_{x}/2} C(x, y) dx dy = \frac{l_{x}^{2} \cdot l_{y}^{2}}{64}$$

We divide symbol picture over n_s cells. The relative position and number of cells depends on contour of symbol.

Now each cell has coordinates (x_i, y_i) and weight of $C(x_i, y_i)$, the total weight of an image on the given picture being as follows:

$$\sum_{i=1}^{n_{x}} C(x_{i}, y_{i})$$

where summation proceeds over cells having brightness differing from zero.

Function C(x, y) can be interpreted as a value of deviation of cell coordinates from center of SP. By virtue of this function we can estimate the value of distortion (tension, compression, inclination) for the symbol image structure's elements.

Let us consider a symbolic image. It is located on ncells of SP and has coordinates (x_i, y_i) . For each cell we will assign its rate of appearance on symbol picture considered — "image is a set of s-invariant probability measures P defined on image algebra" [8];

— the principle of maximum entropy reads that for drawing the inference based on incomplete information it is necessary to use such a probability distribution whereat maximum entropy is reached under certain restrictions;

— the above principle enables us to introduce a limiting information of uncertainly, thus making it possible to construct a statistical model of symbolic images, as well as to develop an algorithm for symbolic pattern classification using parameters of this model.

$$p_i = \frac{\omega_i}{\sum_{i=1}^n \omega_i}, \quad i = 1..n$$
(2)

where ω_i is brightness (the number of pixels) of *i*-cell with coordinates (x_i, y_i) .

Then entropy of the given picture is

$$H=--\sum_{i=1}^{n}p_{i}\cdot\ln\left(p_{i}\right).$$

Maximization of function $H(p_1,..,p_n)$ produces smoothing effects [9], *i. e.* the probabilities p_i and p_j approach each other with the brightness between ω_i and ω_j respectively approaching each other as well.

For pictures of one and the same image we need obeying the constraint on possible probability distributions p_i .

$$\sum_{i=1}^{n} C_i \cdot p_i = a_s, \quad \text{where } C_i = C(x_i, y_i).$$

It is value of possible image distortion on the given picture.

Finally we have a variation problem:

Define ω_i values, which maximize the function:

$$H = \sum_{i=1}^{n} p_i \cdot \ln(p_i)$$
(3)

under constraints

$$\sum_{i=1}^{n} C_{i} \cdot p_{i} = a_{s}, \qquad \sum_{i=1}^{n} \omega_{i} = \omega^{0}.$$
 (4)

This is a typical problem of finding the conditional extremum which can be solved by virtue of the Lagrange method of uncertain multipliers [10]. In addition to restrictions (4) it is necessary to use a standard condition:

$$\sum_{i=1}^{n} p_i = 1$$

Then we will find extremum of function:

$$J = -\sum_{i} p_{i} \cdot \ln(p_{i}) - \beta \sum_{i} C_{i} \cdot p_{i} - \gamma \cdot \sum_{i} p_{i}.$$
 (5)

The following distribution makes maximum available for function (5):

$$\widetilde{p}_i = \frac{e^{-\beta C_i}}{\sum_i e^{-\beta C_i}}, \quad \widetilde{\omega}_i = e^{-\beta C_i}, \quad \beta = -\frac{1+\gamma}{a_s}$$

This maximum is $-2*(1+\gamma)$.

The problem of classification

Criterion of maximum entropy picks up from the p_i distributions, that one which matches the minimum structure information of the symbol image under certain conditions. By virtue of this distribution we can define ω_i values.

Now we can characterize the pictures of one and the same image by the following parameters:

1)
$$a_s = \sum C_i \cdot \frac{\omega_i}{\sum \omega_i}$$
 — extent of possible distortion.

- 2) $\beta = -\frac{1+\gamma}{a_x}$ -- coefficient of average measure.
- 3) Expected value:

$$M\omega_i = \sum \widetilde{\omega}_i \cdot \frac{e^{-\beta C_i}}{\sum e^{-\beta C_i}} = \frac{\sum (e^{-\beta C_i})^2}{\sum e^{-\beta C_i}}.$$

4) Variance:

$$D\omega_i = M (\widetilde{\omega}_i - M\omega_i)^2 = \frac{\sum (e^{-\beta G})^3}{\sum e^{-\beta G}} - \left(\frac{\sum (e^{-\beta G})^2}{\sum e^{-\beta G}}\right)^2.$$

From the stated above we can conclude that these parameters for pictures of one and the same image are nearly equal, thus featuring any class.

Software development

The development of software implies 3 stages:

- program realization of algorithm for computation of symbol parameters;

- verification of validation and obtaining of experimental results for symbol parameters;

- creation of database for working with different handwritten manuscripts.

At present we have completed the first stage. The software was elaborated on 486DX2-80 computer by

By "class" we mean the probability distribution of
brightness
$$\tilde{\omega}_i$$
 from SP center for primary standard symbol
image. This is a distribution whereat maximum entropy is
reached under restrictions (4) and with a certain weighing
function (1).

For arbitrary symbol picture we compute a probability distribution whereat maximum entropy is reached. Then given picture has another probability description. We compute parameters 1) - 4. The problem of symbol classification is solved by virtue of computation of minimum distance between parameters of a given picture and parameters of primary standard image.

If we take into account the problem of symbol identification, then this approach permits the parameters to be introduced for different symbols inside one and the same class:

— ω_i square deviation of a given picture from $\widetilde{\omega}_i$ values of primary standard image:

$$\Delta\omega^2 = \sum \left(\omega_i - e^{-\beta C_i}\right)^2$$

- deviation of entropy from maximum entropy Hmax.

These parameters offer scope for separation of symbolic images corresponding to different handwriting styles and calligraphic writing.

"Borland Delphi for Windows", so it could be used on Mac computers (under Windows for Mac) as well.

Main window of application is shown on fig. 1.

We can load and save graphic files (format *.bmp). With the files being loaded, we can correct fragments of a picture: draw, clear and drag (*fig. 2*).

The technique of operation is as follows:

 — in one paper of handwritten manuscript we consider one and the same symbol;

Res Pen









Fig. 3







- this symbol is discriminated from text by a "Rectangle" tool;

- symbol parameters are computed by pressing "Edges" button.

In fig. 3 we can see the result. Symbol parameters are displayed.

In computing a series of symbols, average of a_s parameter will be shown on screen.

For convenience of research we can cut off necessary symbols from different papers and locate them on one screen (see *fig. 4* and 5).

Conclusion

The statistical model was described to represent a symbol image and the parameters corresponding to the given image. They were obtained by virtue of this model. These parameters are irrespective of angle of turning.

As the images are compared and discriminated for configurations of the most indeterminate structure, not by their original picture, one can suppose that, due to a weighing function, these parameters are nearly the same for parameters of symbols of one and the same class and greatly differ from those of diverse classes.

Computation of these parameters is simple and their use makes it possible to develop a high-speed classifying algorithm.

In one of the following issues we hope to publish the results of the first tests conducted.

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Tables

Table 1

Asiatic Museum (data-base) Preliminary structure of the Arabic MSS description (first level)

- Kecord No.	- Excipit (text file)
Record Author	— Complete (yes/no)
— Record Date	Language(s) (other than Arabic)
— Finished level (1/2/3)	
	— Date of copying
Country	- Place of copying
- City	- Name of copyist
- Library	Colophone (yes/no)
— Shelf number/nress-mark	— Owner's notes (yes/no)
work = MS	— Certificates (<i>ijāza, samā', airā'a</i> , etc.) (ves/no)
$m_{aim\bar{u}'a}$ (folios 000 - 000)	-Waaf note(s)
voluminous	- Seals (ves/no)
No. 1. d. C. d.	A cauired from:
- Number in the Catalogue	- Used in publication (ves/no)
Number of microfilm	Additional information
— Bibliography (GAL, GAS, Graf, etc.)	— Additional information
	Number of Learner
— Author (compiler or translator) (identified or not)	- Number of leaves:
if yes:	— Material: Paper/Parchment/Papyri
name, date of birth/death	- Codex/Scroll
shuhra	— Binding (yes/no)
— Century	— Case for keeping the MS (yes/no)
Title (identified or not)	Ink: colour
if yes:	for the main text
title (as in GAL/GAS)	rubrics
title (according to MS)	verses
- Unique or not	hawāshin
- Autograph or not	etc.
Autograph of not	— Hand
ather MSS according to CAS/CAL or other courses	for the main text
We sublished (VOI)	hawāshin
- was published (Y/N)	Illustrations (ves/no)
il yes:	- Illuminations (ves/no)
bibliographical data	Mistāra (ves/no)
	Physical condition (good/satisfactory/had)
— Incipit (text file)	- Thysical condition (good/satisfactory/bad)

Table 2

Asiatic Museum (data-base) Preliminary structure of the Arabic MSS description (second level)

— Record No.	name, date of birth/death
— Record Author	shuhra
- Record Date	— Century
— Finished level (1/2/3)	Title (identified or not)
	if yes:
— Country	title (as in GAL/GAS)
- City	title (according to MS)
— Library	— Unique or not (Y/N)
— Shelf number/press-mark	— Autograph or not (Y/N)
work = MS	if not:
$maim\bar{u}'a$ (folios 000-000)	other MSS according to GAS/GAL or other sources
voluminous	— Published (Y/N)
Number in the Catalogue	if yes:
Number of microfilm	bibliographical data
= Number of microfilm	— Subject
— Bibliography (GAL, GAS, Grai, etc.)	— Arrangement of the text (free description)
	— Incipit (image file)
— Author (compiler or translator) (identified or not)	Incipit (text file)
if yes:	— Excipit (image file)

Excipit (text file)		type: Oriental/Eu	iropean				
Complete (yes/no)		material: leather/half-leather/cardboard					
incomplete at the beginning		flappered (Y/N)					
incomplete at the beginning		stamping (Y/N)					
at the end	-	- Case for keeping the MS (yes/no)					
number of folios missing		if yes: brief description					
Language(s) (other than Arabic)		Ink: colour for the main text					
— Date of copying		rubrics					
where date comes from:		verses					
colophone		hawāshin					
title page		etc.					
marginalia	-	— Hand					
indirect dating (century)		for the main text					
- Place of copying		marginalia					
- Name of copyist	-	 Illustrations (yes/n 	0)				
- Colophone (yes/no)		if yes: pp. 000-0	000				
II yes:	-	- Illuminations (yes/	no)				
convist's		If yes: pp. 000-0	000				
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image file		one or more					
- Owner's notes (yes/no)		if more					
if yes: names and dates		folios No-s f	or each on	e			
Reader's notes (yes/no)		type of mista	ira:				
if yes: names and dates		for the writte	n area onl	у			
folios No:		with side rul	ing				
- Certificates (<i>ijāza, samā', qirā'a</i> , etc.) (yes/no)	a	dditional information	I				
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arrangement of sheets: matching sides/opposite		ext Width/Height	000	000	000	000	
quire starts with: flesh-side/hair side		age Area (.01s.qm)	000	000	000	000	
- Type of MSS (Codex/Scroll)		ext Alea (.015.qll)	000	000	000	000	
if codex:		nner/Lower Margin	000	000	000	000	
Format: oblong/vertical	In	ner/Outer Margin	000	000	000	000	
Quiring	U	pp.+Low./Text Hgt	w./Text Hgt 000 000 000			000	
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number of folios in gatherings		i	1	I	I	1	
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Type of sewing (if possible)	L	Linear Density 000 Signs/ 10 cm					
Catchword (ves/no)		Spatial Density 000 S	igns/ 10 cr	nĩ			
if yes:	_	Physical condition (good/satisfactory/bad					
additional information		+ additional notes)					
Binding (yes/no)	-	— Additional Bibliography					
if yes:	-	- Additional notes for	or the whol	le MS			

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Table 3

Asiatic Museum (data-base) Preliminary Scheme of Early Qur'ānic MSS Description (third level)

- 27			
	- Record No.		hair f
	- Record Author		thickr
	- Record Date		arrang
	— Finished		quire
	3rd level (ves/no)		parch
	Que en la companya de		P
	— Country		i
	— City		
	— Library		i
	- Shelf number/press-mark		if pap
ĺ	— Number in the Catalogue		
	- Number of microfilm		- Codex/
ļ	— Bibliography		if cod
			F
	— Incipit (image file)		
	Incipit (text file)		
	— Excipit (image file)		
	Excipit (text file)		
	— Complete (yes/no)		
	if fragment:		1
	sūra and āya numbers		
	number of folios missing		Binding (y
	 — Connection with any known regional counting system 		if yes
			t
	— Owner's notes (yes/no)		n
	if yes: names and dates		
	— Reader's notes (yes/no)		
	if yes: names and dates		— Case fo
	Waqf note (yes/no)		if yes
	if yes:		— Palaeo
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	commissioned by		files t
	where donated		Ink
	when donated		for th
	Hijra date:		d
	A.D. date:		, v
	who copied		<i>a</i>
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	A D date.		- aya
	where conied		ii yes
	Formulae:		
	at head		
	within the text		
	at end		
	is waaf note contemporary to the text (ves/no)		if yes (any
	if yes: (limitation of data reliability, if obtained		to the
	without physical methods) — all <i>waaf</i> notes must form		if obt
	the image file.		if yes
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	— Material: Parchment/Papyri	1	*** juz
	if parchment:		if yes
	distinguishable sides-scratching: visible/not visible		of dat

ollicles: visible/not visible ness: fine/medium/thick or combination gement of sheets: matching sides/opposite starts with: flesh-side/hair side ment sheets: outer/inner/both outer (yes/no) f yes: outer sheet starts with: nner (yes/no) f yes: inner sheet starts with: oyri: Scroll lex: format: oblong/vertical Duiring number of gatherings, number of folios in gatherings structure of quires numbering of quires ype of sewing (if possible) es/no) ype: Oriental/European naterial: leather/half-leather/cardboard flappered (Y/N) stamping (Y/N) or keeping the MS (yes/no) brief description graphical Data: es of alif, lām, qāf, existing ligatures form image to be anlysed by specialised software. e main text liacritics owel marks iya separators lluminations and decorations a separators (yes/no) : their position: etween all āya each five āva each ten *āya* other groups of *āya* (yes/no) if yes: what groups: āya separators): are they contemporary text (yes/no) (limitation of data reliability, ained without physical methods) (any aya separators): what is the shape of ators: ative (form the file of images, which must contain dditional comparative material of ornaments, ations and illuminations from architectural and written ments dated by II/VIII-III/X centuries -- common ith the points of description marked by ***) ' and hizb separators (yes/no) s: are they contemporary to the text (yes/no) (limitation a reliability, if obtained without physical methods)

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two earliest dated papyri d. of Muhammad





Notes

1. E. Rezvan, I. Tikhonova, "Bazy dannykh po rukopisnym sobraniiam: problemy i perspektivy (k nachalu osushchestvleniia programmy)" ("The data-bases on manuscripts' collections: the problems and perspectives (on the beginning of the programme)"), Bazy dannykh po istorii Evrazii v Srednie veka, fasc. 1 (Moscow, 1992), pp. 55-63.

2. The schemes for the first and the second levels were jointly proposed by E. Rezvan, Val. Polosin, VI. Polosin. As for the description of the Qur'anic manuscripts (the sample of the third level description), it was elaborated by E. Rezvan. Codicological information for the third and for the second levels is treated on the basis of approach elaborated within the Hebrew Paleography Project by Professor Malachi Beit-Arié and his colleagues.

3. E. Rezvan, "The data-base on the early Qur" an MSS: new approach to the text history reconstruction", *Proceedings of the 3rd International Conference and Exhibition on Multi-Lingual Computing (Arabic and Roman Script)* (Durham, 1992), 3.3.1—3.3.17. Also see *idem*, "Computer methods in Qur" and studies", *Proceedings of the Conference on Bilingual Computing in Arabic and English* (University of Cambridge, 1990), pp. 1—7.

4. Because of the financial shortages only little part of the project have been realized up to now. About the work on the project see, in particular, *Manuscripta Orientalia*, 1/3 (1995), pp. 47—62 (Arabic OCR project); *ibid.*, 1/1 (1995), pp. 53—5 (the data-base on Muslim seals); *ibid.*, 11/1 (1996), pp. 51—3 (Tibetan data-base) and the present article.

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