Script Characterization in the Old Slavic Documents

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Abstract. The paper addressed the problem of the script characterization in the old Slavic printed documents. Therefore, an algorithm for the script discrimination was proposed. It was based on the typographical feature classification, which creates ciphers from different scripts of the document. Then, the feature extraction was achieved by statistical analysis. The obtained features were set and stored for further analysis in order to identify the discrimination criteria between different scripts. The proposed method is tested on the example of the Slavic printed documents which contains Glagolitic and Cyrillic script.

Keywords: Cryptography, Script recognition, Optical character recognition, Statistical analysis, Typographical features.

1 Introduction

Optical character recognition (OCR) is a computer based system that recognizes the scanned printed, hand printed or handwritten documents. It consists of a few stages such as: preprocessing, feature extraction, classification and post-processing [1]. One of the main parts that represents the feature extraction stage is a script recognition module.

In this paper, we introduced an algorithm for the script recognition based on typographical features, cryptography and statistical analysis. This method established discrimination criteria for the identification of different scripts in the old Slavic printed documents. In its first part, the algorithm classified all letters according to their typographical features. Then, the data were encrypted creating cipher [2]. The encryption was made by a cryptographic algorithm [3] that belongs to hash function (HF) [4]. It irreversibly encrypted the initial information. Nevertheless, the cryptography was used as a base for modeling only [5]. Hence, decryption was not required. This way, the model was established by replacing each letter in the text with the cipher using a similar approach as in [5]. After that, the gray-level co-occurrence matrix (GLCM) was calculated to extract the certain texture features [6]. The analysis of these features were

made along with their classification. At the end, the criteria for discrimination between scripts was established.

The rest of the paper is formed as follows: Section 2 addresses all aspects of the proposed algorithm. It includes script mapping, encryption, co-occurrence analysis, and features extraction. Section 3 defines the custom oriented script database for the experimentation. Section 4 discusses the results of the experiment. Section 5 makes conclusions.

2 Proposed Algorithm

The proposed algorithm consists of the stages that follows: (i) script mapping, (ii) encryption, (iii) co-occurrence analysis, and (iv) features extraction.

2.1 Script Mapping

All letters in certain script have different typographical features according to their position in the text line [7]. Hence, the structure of the text line can be divided into: (i) upper zone, (ii) middle zone, and (iii) lower zone [8]. Short letters (S) like a small letter **a** are located in the middle zone. Ascender letters (A) like capital letter **k** outlay the middle and upper zones. Descender letter (D) like small letter **p** outspread over the middle and lower zone. Full letters (F) like the capital letter **j** occupy all three zones. Fig. 1 illustrates the script type definition.

Fig. 1. Script type (ST) illustration: (a) Letter samples, and (b) Equivalent script types

Consequently, all letters from different scripts in the old Slavic documents are mapped into the script type set ST :

$$ST = \{S, A, D, F\}. \quad (1)$$

2.2 Encryption

The data needs to receive a form that is suitable for the statistical analysis. Hence, the set ST is encrypted into the cipher set C .

$$C = \{0, 1, 2, 3\}, \quad (2)$$

where $S \rightarrow 0$, $A \rightarrow 1$, $D \rightarrow 2$, and $F \rightarrow 3$. Fig 2. illustrates Cyrillic and Glagolitic alphabet according with their cipher counterparts.

а	б	в	г	д	е	ж	з	и	ј	к	л	љ	м	н	њ	о	п	р	с	т	ћ	у	ф	х	ц	ч	ш	
0	1	0	0	2	3	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	1	2	3	0	2	0	2	0

(a)

А	Б	В	Г	Д	Е	Ж	З	И	Ј	К	Л	Љ	М	Н	Њ	О	П	Р	С	Т	Ћ	У	Ф	Х	Ц	Ч	Ш	
1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	3	1

Ѡ ѡ Ѣ ѣ Ѥ ѥ Ѧ ѧ Ѩ ѩ Ѫ ѫ Ѭ ѭ Ѯ ѯ Ѱ ѱ Ѳ ѳ Ѵ ѵ Ѷ ѷ Ѹ ѹ Ѻ ѻ Ѽ ѽ Ѿ ѿ Ѡ ѡ Ѣ

Fig. 2. Encryption: (a) Cyrillic alphabet and cipher counterparts, (b) Glagolitic alphabet and cipher counterparts

2.3 Statistical Analysis

The proposed algorithm exchanges all letters from a certain script with the equivalent members of the set C (See Fig. 2 for reference). The obtained cipher is subjected to a co-occurrence analysis [6]. This way, the texture features is calculated according to co-occurrence probabilities. These probabilities represent the conditional joint probabilities of all pair wise combinations of gray levels in the spatial window of interest (WOI). Three parameters can be considered in order to describe the image with GLCM: (i) the number of gray levels (G), (ii) the orientation angle (θ) and (iii) the length of displacement, i.e. the inter-pixel distance of the window of interest (d) [9]. Fig. 3 illustrates the window size for calculating the Haralick texture features.

The method starts up in the top left corner and counts the occurrences of each reference pixel to neighbor pixel relationship. This way, each element (i, j) of GLCM is the sum of the number of times the pixel with the value i was located at some distance d and angle θ from the pixel of intensity j . At the end

69	0	9	5
0	0	0	0
9	0	2	2
6	0	2	0

(a)

69	4	9	4
6	0	0	0
8	1	0	0
4	0	0	0

(b)

Fig. 5. GLCM obtained from the cipher (Fig. 4): (a) Glagolitic text encryption, and (b) Cyrillic text encryption

The probability version of the GLCM is given as:

$$C(i, j) = \frac{P(i, j)}{\sum_{i,j} P(i, j)} \quad (4)$$

2.4 Features Extraction

The number of texture features that can be extracted from the GLCM is 14 [6], [9]. Due to the similar origin of the Cyrillic and Glagolitic script [10] only four texture features is used. These four features are defined as:

$$\text{Dissimilarity} = \sum_i^G \sum_j^G C(i, j) \cdot (i - j) \quad (5)$$

$$\text{Contrast} = \sum_i^G \sum_j^G C(i, j) \cdot (i, j)^2 \quad (6)$$

$$\text{Invdmoment} = \sum_i^G \sum_j^G C(i, j) \cdot [1 + (i - j)^2] \quad (7)$$

$$\text{Homogeneity} = \sum_i^G \sum_j^G C(i, j) \cdot [1 + (i - j)] \quad (8)$$

3 Experiment

In the experiment, the custom oriented database that mainly consists of the documents given in [11] is adopted for the testing purposes. The database consists of 50 documents with the text length from 700 to 3000 characters. A few texts are written by George d'Esclavonie (i.e. Juraj Slovinać), who was the Croatian Glagolitic priest and professor at Sorbonne in Paris around 1400. They represent excerpts from his book *Le Château de Virginité* (i.e. *The Castle of Virginity*) written in 1411 [11]-[12]. It is given in Fig. 6.

Fig. 6. Document samples excerpt from database: (a) Cyrillic document, and (b) Glagolitic document

4 Results and Discussion

According to the proposed algorithm, the documents from the database were encrypted to cipher and subjected to the co-occurrence analysis. The four GLCM texture features, i.e. dissimilarity, contrast, invdmoment and homogeneity were used to characterize the scripts. To evaluate the results, the minimum, maximum and mean values were used. Tables 1-2 show their values for Cyrillic and Glagolitic script, respectively.

These measures showed significant variation for both scripts. Hence, it is a starting point for their discrimination. Cyrillic script was characterized with

Table 1. Results of the experiment for Cyrillic text

Cyrillic	Dissimilarity	Contrast	Invdmoment	Homogeneity
Minimum	0.5770	1.0649	0.7281	0.7641
Maximum	0.6577	1.2275	0.7603	0.7920
Mean	0.6150	1.1518	0.7462	0.7807

Table 2. Results of the experiment for Glagolitic text

Glagolitic	Dissimilarity	Contrast	Invdmoment	Homogeneity
Minimum	0.7375	1.6097	0.6723	0.7248
Maximum	0.8659	1.9180	0.7185	0.7638
Mean	0.8103	1.8197	0.6958	0.7449

Fig. 7. GLCM features for Cyrillic and Glagolitic script: Dissimilarity (top), Contrast (middle top), Invdmoment (middle bottom), Homogeneity (bottom)

dissimilarity below 0.66, contrast below 1.23, invdmoment above 0.72 and homogeneity above 0.764. In contrast, Glagolitic script was distinguished with dissimilarity above 0.73, contrast above 1.60, invdmoment below 0.72 and homogeneity below 0.764. Fig. 7 illustrates the comparison between scripts taking into account these texture features.

To quantify their differences, the ratio between given measures is established. Table 3 shows these ratio measures.

Table 3. Texture feature ratio measures

Cyrillic/Glagolitic Ratio	Dissimilarity	Contrast	Invdmoment	Homogeneity
Minimum	0.6811	0.5602	1.0270	1.0122
Maximum	0.8568	0.7273	1.1270	1.0911
Maximum	0.7613	0.6355	1.0729	1.0483
Criteria	< 1	< 1	> 1	> 1

From the results given in Table 3 the discrimination criteria can be established. It is clear that dissimilarity and contrast received lower values for the text written in Cyrillic compared to the text written in Glagolitic script. On the contrary, invdmoment and homogeneity acquired higher values. Accordingly, these descriptors are suitable for establishing the discrimination between Cyrillic and Glagolitic script. The synergy of these four descriptors can define a strong margin in establishing criteria to distinguish a certain script. As the final result, we expect to create the solid criteria for recognition of the script in the Slavic documents. The criteria can be described with the following pseudo-code:

```

program Script_Distinction (Output)
  If [(Dissimilarity ratio < 1) and (Contrast ratio < 1) and
      (Invdmoment ratio > 1) and (Homogeneity ratio > 1)]
  then
    Output = "Cyrillic text"
  else
    Output = "Glagolitic text"
  end
end.

```

The proposed algorithm is characterized as computationally non-intensive. It is coded in Matlab without any programming parallelism. Testing indicated that typical processing time is as low as 0.1 seconds per text including around 2000 characters.

5 Conclusion

The paper proposed the algorithm for the script characterization and identification in the old Slavic printed documents that incorporate Cyrillic and Glagolitic

scripts. The algorithm included the statistical analysis of the document based on the baseline status of each script element accompanied with the encryption. The statistical analysis was performed by co-occurrence analysis of the cipher. As a result, four texture features were extracted. Due to the difference in the script characteristics, the results of the statistical analysis showed significant diversity between both scripts. It represented the key point for decision-making process of script identification. The proposed method was tested on documents from the custom oriented database. The experiments gave encouraging results.

Future research will integrate the proposed algorithm into the preprocessing stage of the optical character recognition (OCR).

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