

Classification and Recognition of Neume Note Notation in Historical Documents

Lasko Laskov

Abstract: Neume musical notation is a type of writing of Christian Orthodox Church chant originated in Ancient Byzantium, which is still used by the Orthodox Church. The big varieties of preserved historical documents, which contain neumes give reach material for investigations in fields like history, cultural sciences, etc. This causes the natural need of a software package which can help these investigations. Such software can be OCR (Optical Character Recognition) based which will help the analyses of the neume notation in the scanned historical documents. In this paper we present an overview of the methods, which can be used to create a system for automated recognition of neumes.

Key words: historical document image processing, neume notation

INTRODUCTON

During the last years a lot of investigations in the field of OCR (Optical Character Recognition) and Document Image Processing have been made. A number of commercial software packages were created which successfully transform scanned document image to a text file (usually in ASCII format) if the document is written in a standard alphabet (Latin, Cyrillic, etc.) and is with good quality. Unfortunately these tools cannot process successfully historical documents for a number of reasons: bad quality of the document image, non-standard alphabets, and the old documents are handwritten. These difficulties make the problem of processing old documents a challenging task. In this sense, documents which contain neume notation (bibles, medleys of psalms, etc.) are reach source of material for experiments. The special characteristics of neume notation is the reason why its computer recognition is a difficult process whose investigation will lead to improvement of the existing document image processing methods and development of new ones, and also will give a useful tool in the hands of scientists who investigate these manuscripts. Another important reason for research in this direction is the fact that very few attempts to build such systems were made, like the work of Gezerlis [1, 2]. His method gives good results for printed documents, created after 1814 but there is no research for older handwritten documents. Also, the difficulties connected with processing old manuscripts of poor image quality are not considered. On the other hand, a lot of other examples of non-standard OCR problems are known, some of them successfully solved [7], for example, for texts written in old alphabets, classical musical notation and so on. In each of these problems there is a concrete specific characteristic which is used for its solution but also impede the standard OCR techniques to solve them. So is the examined case – automated and possibly automatic computer analysis and recognition of neume musical notation in old historical documents.

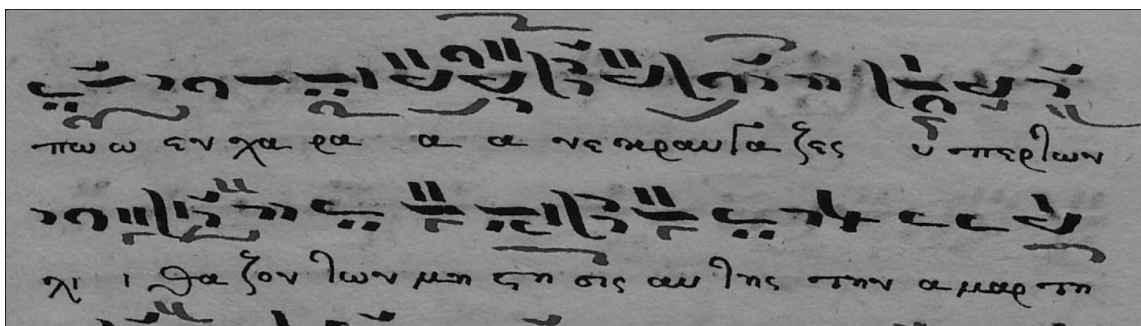


Figure 1. Fragment of document containing neume notation

SPECIAL CHARACTERISTIC OF NEUME NOTATION

Neume notation consists of number of symbols which are written on top of the psalm text and indicate the way it must be performed denoting tones, intonation, etc. Thus, the documents which contain neumes consist of two types of lines which alternate with one another – neume lines and text lines (Figure 1). Each neume is a connected component and is alphabetical notation the same way Latin and Cyrillic letters are. This means that a tone and a way to perform it are represented by a combination of neumes. The contemporary neumes which are used now-a-days by the Christian Orthodox Church can be classified in three main categories: quantitative, qualitative and temporal. In [1, 2] Gezerlis indicates 71 distinct symbols which are accepted as standard since 1814. Also, it is interesting to mention that these neumes are part of the Unicode standard, version 4.1. But in our case we are interested in the old manuscripts where the variety of the neumes is much bigger, since they were changing during the ages. The historian Jean-Baptiste Thibaut who was one of the first to investigate the neumes mentions three major periods of development:

1. Early period - when the signs have no distinct intervallic value;
2. Middle period - when intervals between notes are clearly indicated;
3. Late period in which additional symbols are added in red ink to the normal neume notation, which is written in black ink.

Besides that, in the late periods each copyist had his own style of writing the neume notation. All these shows the vast variety of classes in which the neumes contained in old manuscripts can be divided. One possible system which will process such documents must be flexible enough to find the similarities and differences between the symbols of the different periods.

Another important characteristic of the neume notation is the way it is interpreted. One tone (or the way the psalm should be performed in the precise moment) is denoted by complex combination of symbols. This means that the interpretation of a neume is highly dependent on its context. Additional difficulty is the fact that some of the symbols differ in small details or in their orientation in the document (some neumes differ only in an angle of rotation).

SPECIAL CHARACTERISTIC OF HISTORICAL DOCUMENTS CONTAINING NEUME NOTATION

Big part of the documents containing neume notation and being an object of research are historical documents of bad quality of the paper (parchment), the text (letters, symbols) are not well visible and contain noise like stains, folded regions, etc. Processing such documents requires special approaches for document image enhancement like removing the noise and an intelligent problem-oriented binarization (separation of the symbols from the background). A good example of such technique is the one proposed by Gatos in [3], but it is designed for processing documents containing old Greek calligraphy.

STAGES OF PROCESSING OF DOCUMENT IMAGES CONTAINING NEUME NOTATION

Basically the stages of processing of document images containing neume notation can be separated in three main parts:

1. Methods for preliminary processing of the document image from a quality point of view.
2. Methods for segmenting, classification and recognition of the distinct neumes contained in the document.
3. Methods for context analysis of the structures formed by the neumes, with the aid of computer linguistic, multicriteria optimization and artificial intelligence.

In the first part methods for document image pre-processing are included such as algorithms for noise reduction, quality enhancement and intelligent binarization

(emphasizing the neumes and other characters compared to the background). The second part of the processing includes line segmentation, separation of the neumes notation lines from the lines containing the text of the psalm, the segmentation of the distinct neumes and their recognition (partially and in combinations). The final stage is the semantic and context analysis of the recognized symbols and their musical meaning in the cases it is possible, because for most of the ancient documents the interpretations of the neumes and their combinations are not known.

NOISE FILTRATION AND DOCUMENT IMAGE ENHANCEMENT

Noise filtration and document image enhancement is an important step in processing of historical documents and document images of poor quality. The goal of this stage is smoothing the background texture and increasing the contrast between the background and the regions containing neumes and/or text. Another goal is to achieve effectiveness in combination with the binarization stage (separation of the background and neume/text regions). Classical examples of such approaches are the low-pass smoothing filters, Kalman's statistical optimal filters, Wiener filter [4], etc. Here solutions optimal for the concrete case must be developed.

OBJECT EMPHASIS BASED ON IMAGE BINARIZATION

Binarization is segmentation of an image in two levels using the scheme "black object on white background". However in our case the colour information is important since it has meaning for the neume notation interpretation in some of the documents, so the emphasis approach must segment the document image in more than two levels. The goal of binarization is background separation and removing all the objects from the document image which have no meaning for the next recognition stage. The most popular methods for image binarization are based on histogram analysis. There are two types of binarization approaches – global (a signal, optimal in some sense threshold is selected) and local in which the binarization threshold in the different parts of the image can be different. Usually the global binarization approaches are not suitable for processing document images of poor quality because of its noisy nature. A classical example for global method is the method with optimal threshold proposed by Otsu. Another example is the method of Kittler which provides minimal Bayes' error of binarization.

On the other hand local-adaptive methods for binarization adjust themselves depending on the local information and are more flexible even for processing documents of poor quality. Most of them are based on statistical information in some small area, as the method of Niblack [5] and require a priory knowledge for the image content. Comparison between some of the binarization methods can be found in [5].

ANALYSIS AND RECOGNITION OF DISTINCT NEUMES

After the document image pre-processing stage follows the analysis of its content. The input data for this stage is the denoised and binarized image of the scanned document. The following steps must be performed:

1. Document line segmentation.
2. Symbol segmentation – extraction of the distinct neumes from the segmented lines.
3. Distinct neumes recognition.

A successful method for line segmentation is the one based on Hough transform [6]. After the line segmentation is performed, we can easily separate the lines containing neume notation from the text lines because of the typical structure of this type of documents, which is mentioned above.

The segmentation of the neumes from the segmented lines can be performed using vertical projection of each line where the local minimum of the projection indicates the empty space between the symbols. This technique is applicable for the ancient

manuscripts because the characteristics of the writing are close to the printed letters – the letters are written in standard way and they have no slant.

In [1, 2] Gezerlis proposes a method for recognition of distinct neumes based on Wavelet Transform (WT). This method works well for documents created after 1814, but they are printed and contain a reduced number of neumes – 71. As mentioned above, in the older historical documents the variety of the neume notation is much bigger. Also, classical WT methods are highly dependant on the symbol rotation, which is important in our case since the documents are handwritten and local rotations of the symbols are highly possible (accidental or because of the calligraphy). In this case, a pre-processing step is needed to compensate symbol rotations before using of the WT method. In this sense, methods based on Fourier Transform are also a good solution since the rotation invariance is easier to achieve. Also, the noise filtration is also done in the frequency (Fourier) domain.

A possible approach for distinct neumes recognition can be based on neuron networks, which is one of the most popular methods for character recognition used in most of the commercial software. A serious drawback here is that the learning step is very time and effort consuming.

CONCLUSION

After the distinct neumes are successfully classified (recognized), follows the most challenging step of analyzing the structures they form and giving an interpretation of the neume notation. Because of the complexity of these structures the problem of their interpretation is sophisticated combinatorial problem since there is big variety of different criteria.

One possible solution can be based on multicriteria analysis, which is a technique for solving problems which depend on big number of parameters. Another approach can be based on computer linguistics, which is a common method for automatic text analysis. In this case a parser-based system can help the user to analyse the meaning of the neume notation in the document.

Since there are a lot of uncertainties for interpretation of neume notation in the older manuscripts, an expert knowledge is required to analyse their meaning. In this sense, a knowledge-based module can be designed to assist the expert in neume notation analysis.

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ABOUT THE AUTHOR

Lasko Laskov, PhD student, Informatics Dep., New Bulgarian Univ., llaskov@nbu.bg