Detecting the Staff-Lines of Musical Score with Hough Transform and Mathematical Morphology

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Detecting the Staff-lines of Musical Score with Hough Transform and Mathematical Morphology

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***Abstract*—This paper presents conventional architecture of Optical Music Recognition (OMR), staff-lines detection is a key stage in OMR. It explains two major methods of staff-lines detection in detail, and it selects 68 images to experiment for the methods. The result of experiment indicates that two methods both can detect all staff-lines of an image by Hough Transform and Mathematical Morphology, but the runtime of Hough Transform is long than Mathematical Morphology.**

Keywords- Optical music recognitio; Musical score; Staff-lines detection; Hough Transform; Mathematical Morphology

I. INTRODUCTION

Notation is a method for recoding music, there are various music notation in the music history, such as Common Music Notation (CMN), Numbered Musical Notation, Chinese Tradition Gong-Chi Notation, Chinese Tradition Abbreviated Character Notation and so on. The notation was required to recode all musical activity, such as pitch, loudness, duration, timbre, expression symbols and so on.

CMN is a notation most widely used in the world now, it also called Western music notation or Western staff notation, a lot of paper musical score using CMN are in public libraries and private collection, some excellent musical works don't be used and the public don't family with them. Meanwhile, the public prefer to listen audio musical works, for example MP3 music, some people don't understand a musical score. In other words, the musical score must transform to acoustic form by a performer, then the musical works can be familiar with the public.

Optical Music Recognition (OMR) is the process of automatically extracting musical meaning from a musical score by a computer, OMR sometimes also be called musical score recognition, it uses synthetically some techniques which include image processing, pattern recognition, AI, MIDI and so on, it can transform paper musical scores into musical audio, and it is a basic way to apply to digital medium music data, large digital music library, robot reading musical score and automatically perform, computer music education, Chinese tradition music digitalization [1].

The process of OMR from a paper musical score briefly follows three specially steps, where each step works on the output of the previous one.

(1) The first step is to acquire a digital form of the paper music score and a computer can access. This step is so easy, that can be created a digital image from a paper musical score by the digital equipment, such as a scanner.

(2) The second step is to get musical information by performing various image processing techniques on the musical score image. The musical information derived from all symbol objects of the image, these symbols include staffs, notes, rests, slurs, accents, trills, tempo markings, key signatures, time signatures and so on. This is a main step, and is often broken up into two or more separate steps.

(3) The final step is to store the musical information to a digital form, and a computer can access.

In the second step, several image processing techniques are used that include image binarization, image rectification, image denoising, image histogram, image segmentation, region labeling, object recognition and so on. Image pattern recognition techniques is used for identifying the various musical shapes found on an image, for the musical score, a stage of basic of pattern recognition is to detect the staff , due to most musical symbols of a musical score are laid around the staff lines in a two dimensional manner, the horizontal axis is the time axis while the vertical axis tells the pitch of note symbols. Figure 1 shows the relationship of a staff and some symbols, the staff lines graphically obviously connect most musical symbols. The most long lines in the digital musical score image are stave which include five horizontal lines[2].

II. DETECTING STAFF-LINES METHODS

To a human reader, staff lines of a musical score are important because they help the reader find out precisely the vertical position of musical symbols, likewise in order to recognize all symbols in a musical score, most of OMR systems take a strategy which first detect all staff-lines in an image and second remove these staff-lines from the image, conventional detection methods of staff-lines are following:

- Horizontal and vertical projections
- Hough Transforms
- Mathematical Morphology
- Linear Adjacency Graph

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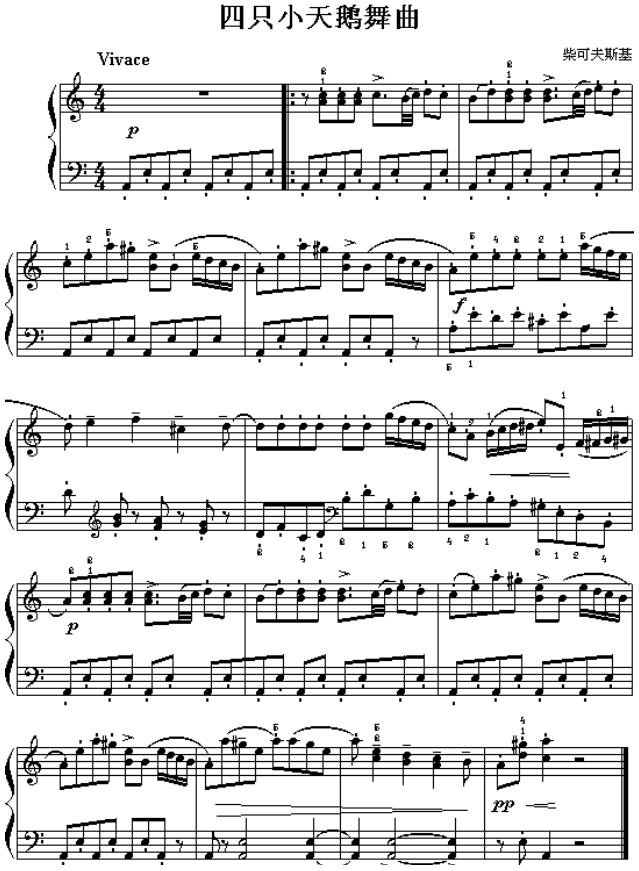

Figure 1. The score of "Dance of Little Four Swans"

Detection of staff-lines is performed via partial horizontal projections, projection is the most straightforward method and was patented by Fujinaga(1988), but this method is sensitive to an image skew, so it requires the degree range of skewing angle of the image is [3]. Figure 2 shows the vertical projection of a fragment of a musical score, sub-image above in Figure 2 is a fragment of a musical score, sub-image underside in Figure 2 is the result of vertical projection.

Hough transform is a method commonly used in image processing for locating straight lines from in an image, it was patented by Hough(1962)[4], it can find out lines in all orientations and positions, and is suitable for detect the staff-lines when the image is skewed, but if an image includes some large amount of musical symbols, many false staff lines were found.

Mathematical Morphology[5] is a powerful set of binary image processing operations, it was from a set-theoretical approach, it uses a structuring element to detect an image, and validates whether the structuring element can fill in the image, the selection of structuring element aims to the result of processing and different structuring element may get different analytical result. Some basic operation of Mathematical morphology can process a musical image to get musical information.

Linear Adjacency Graph was patented by N.P.Carter[6], in this method, the input image is first scanned vertically and vertical runs of black pixels are run-length encoded. An individual vertical run of black pixels is called a segment. A

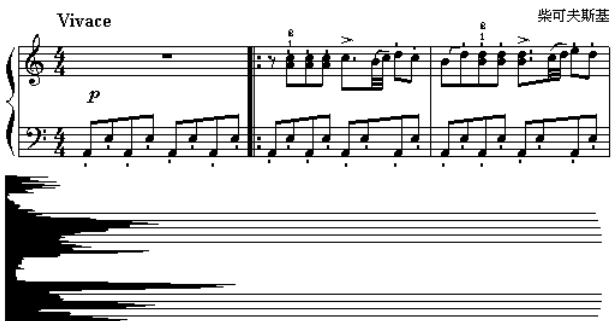

Figure 2. A fragment of a musical score and its vertical projection

transformed Line Adjacency Graph(LAG) is formed by linking together horizontally adjacent segments which overlap vertically. In the construction of the LAG, the vertical run-length encoding is scanned from the left of the image to its right. For musical score image, this method can represent the relation of a staff-lines and other musical symbols.

III. HOUGH TRANSFORM AND MATHEMATICAL MORPHOLOGY FOR THE STAFF-LINES OF MUSICAL SCORE

A musical score images of CMN is a binary image, it includes some lines, such as staff-lines, bar-lines and stem-line of notes, the staff-lines are so long than other musical symbols, so we can use Hough Transform and Mathematical Morphology to locate them.

Hough transform tend do be most successfully applied to line finding, a line in a rectangular coordinate is expressed as:

$$ax + by + c = 0 \tag{1}$$

Meanwhile, a line is easily parametrized as a collection of points such that:

$$x\cos\theta + y\sin\theta + r = 0 \tag{2}$$

Any pair of (θ, r) represents a unique line, where is the perpendicular distance from the line to the origin and , for all points of a staff-line in a musical score image line, the (θ, r) of this line is unique, so using an 2D array to record (θ, r) of every point in musical score image, then it scans the array to count the number of corresponding points of a pair of (θ, r), according to the statistics result to locate all staff in the score image.

Erosion Operation and Dilation Operation are some basic operations of mathematical morphology, for musical score image, they are a good method for staff-lines identification. General Erosion Operation is defined by

$$E = B\Theta S = \left\{x, y \mid S_{x,y} \in B\right\} \tag{3}$$

That is, the binary image E that results from eroding B by S is the set of points such that if S is translated so that its origin is located at , then it is completely contained within B. S is a structuring element.

General Dilation Operation is defined by

$$D = B\Theta S = \{x, y \mid S_{x,y} \cap B \neq \phi\} \qquad (4)$$

That is, the binary image D that results from dilating B by S is the set of points such that if S is translated so that its origin is located at , then its intersection with B is not empty.

For detecting all staff in a score image, the template of structuring element is designed by Figure3, the 1 means object pixel, the 0 means background pixel.

0	0	0
1	1	1
0	0	0

Figure 3. the template of structuring element

IV. THE RESULT OF EXPERIMENT

We had designed an experiment by using some basic operation of Mathematical Morphology and Hough Transform, and had downloaded 68 piece piano scores for testing from Internet[7], these music works all are counterpoint music, and include some works of famous composer and some folk song. All tests used for our comparison were implemented in the Matlab7.0 and compiled under the same condition, and all experimental results presented in this section were obtained on a PC-based desktop computer(Intel Pentium 2.5GHz CPUs, 2GB Memory, Windows XP OS) by use of one core.

Hough Transform can find out the staff in an score image, Figure 3 shows the result of Hough Transform, the top sub-image shows the original image which is a part of the image in Figure 1, the middle sub-image shows the staff-lines of the image by Hough Transform, and the bottom sub-image shows the subtraction of all black pixels between the top sub-image and the middle sub-image. Obviously, the middle sub-image includes the staff-lines and more noises, the noises is the result of other musical symbols by Hough Transform.

Using Erosion Operation and Dilation Operation to identify a staff-line in an image, Figure 4 shows the result of Erosion Operation and Dilation Operation, the top sub-image is an original image and the bottom sub-image is the result, it firstly uses Erosion Operation to process the image, then uses Dilation Operation to process the image, the template of structuring element of Erosion Operation and Dilation Operation was shown Figure 3. Obviously, no noise is in the result image.

Finally, we measure the run-times of Hough Transform and Mathematical Morphology for 68 images, it is got the processing result of these score by Matlab7.0. Figure 5 shows the runtime of Hough Transform and Mathematical Morphology, and Figure 6 shows the ratio of the runtime between Hough Transform and Mathematical Morphology, from Figure 5, all runtime of Hough Transform are large than

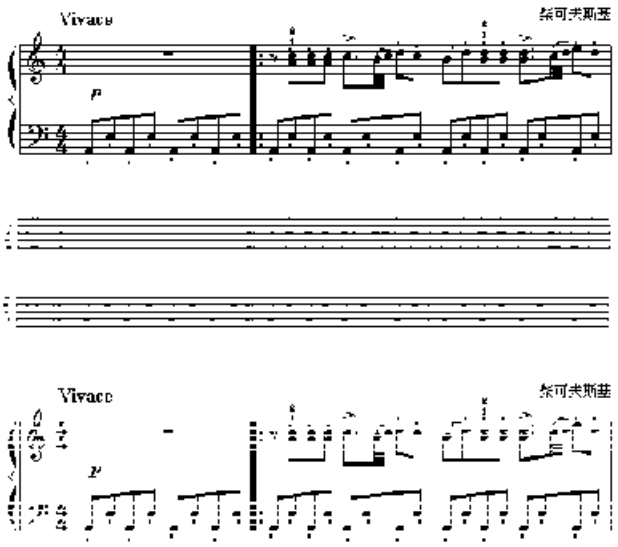

Figure 4. A fragment of a musical score and its Hough Transform

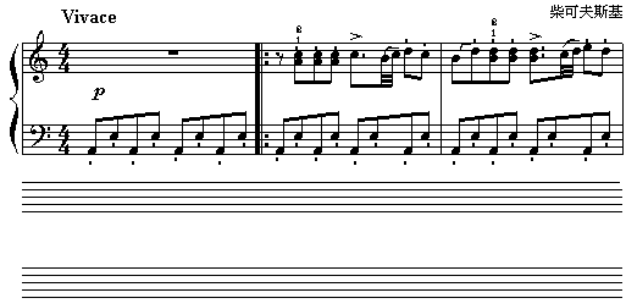

Figure 5. the result of Erosion Operation and Dilation Operation

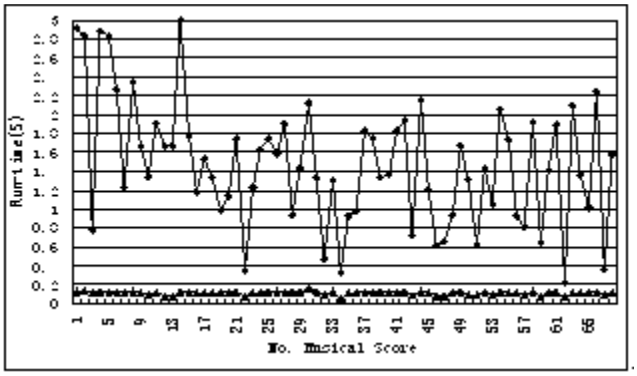

Figure 6. Runtime of Hough Transform and Mathematical Morphology

0.2s,Table 1 shows max, min average runtime and theirs ratio of Hough Transform and Mathematical Morphology. all runtime of Mathematical Morphology are small than 0.2s. From Table 1, the ratio of average runtime between Hough Transform and Mathematical Morphology is 13.28, So we can come to a conclusion: Mathematical Morphology is fast then Hough Transform for finding out a staff-line in an image.

Figure 7. Ratio of the runtime between Hough Transform and Mathematical Morphology

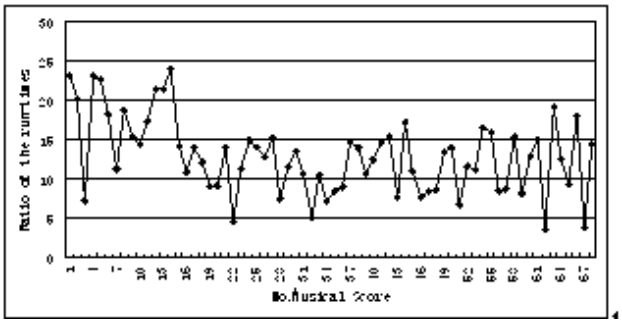

TABLE I. MAX, MIN AVERAGE RUNTIME OF HOUGH TRANSFORM AND MATHEMATICAL MORPHOLOGY

Case	Runtime		
	Hough Transform	***Mathematical Morphology***	***H/M***
Max	3.000000	0.156250	19.2
Min	0.218750	0.046875	4.67
Average	1.471108	0.110755	13.28

V. CONCLUSION

By the experiment of finding out all staff-lines in an musical score image, Mathematical Morphology always show great advantage than Hough Transform, the staff-lines detection is the key phase of the OMR system, the goal is to identify a rectangular area in which the staff is located in order to process that image segment to extract the contained basic music symbols, the staff detection can profit for later phases of OMR system.

Long time, a great of music works had existed based on paper and music notation, the OMR method can transform these to audio form, so the OMR method is a key technique for large music database, digital library, music teaching, music analysis and so on.

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