

# Staff Line Removal Algorithm Based on Trajectory Tracking and Topological Structure of Score

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**Abstract.** Staff line removal plays a vital role in OMR technology, and is the preconditions of succeeding segmentation & recognition of music sheets. For the phenomena of over-deletion or mistaken deletion and under-deletion which often appear in removal process of staff lines, a novel staff line removal algorithm based on trajectory tracking and topological structure of music symbols is put forward to solve the deletion faults of partial notions, Experimental results show the presented algorithms can remove staff lines fast and effectively.

**Keywords:** OMR, Staff Line Removal, Subsection Projection, Correlation Computation

## 1. Introduction

Optical Music Recognition (OMR) is the process of converting paper sheets of music score, which input in computer using scanning device or digital camera, into an electronic format by implementing a series of digital image processing like segmentation, recognition, score reconstruction [2~6], for stance, MIDI, which can be “read” by computer and is suitable further processing such as editing, performing, printing, communication and so on. Unlike conventional image store formats (JPG, TIF, GIF and the like) which compress and store the optical scanning image, OMR file formats record the particular music contents of score sheets, so, less storage space is need compared with the former and the digitalization of magnanimous paper music sheets can be realized. As a result, OMR technology provide a intelligent & high-effective means to realize the digitalization of paper music, which shows a nice application prospect for applying to computer-aid music teaching, digital music library, internet music search, and compute music composition as well [8].

A whole OMR system is mainly composed of five modules[2~5]: 1) namely, 1) input and pre-processing of paper music sheets, 2) detection and removal of staff line of music score, 3) image segmentation of music sheets, 4) music score recognition[7], 5) music sheets reconstruction and music grammar explanation [1]. Staff line is a essential composition part of music sheets, in which many important information is concluded, larger number of music symbols are distributed at or between different staff lines, crossing or overlapping with the lines, and the pitch of music notes is decided by their vertical positions in staff lines. So, staff line deletion is the preconditions of segmentation and recognition of music score, and the deletion accuracy of staff line directly affects the subsequent processing and plays a crucial role at the aspect of OMR system performance.

Because crossing or superposing are often existed between music notes and staff line. Conventional staff line track removal approach often delete some pixels whose total width is less than setted threshold along a checked line, because of absence of macroscopic analysis for those pixels around staff lines, mistaken removal or over-removal phenomenon often occurs, some pixels whose line width is equal to staff line width and superpose with staff line often are deleted and lead to destroy the integrality of music notation, just as

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Fig. 1. As a result, next music recognition will become more complex and difficult, and reduce the recognition rate of music notation, on the contrary, run-length graph slice method adopts a full different approach, because the removal of staff lines is executed according to the macroscopic feature of the graph slices, the phenomenon of mistaken removal can be avoided at certain content, but the problem of under-removal may be arisen, shown as Figure 2. For the cases, an algorithm based on trajectory tracking and topological structure of music symbol



Fig. 1 Over-removal phenomenon

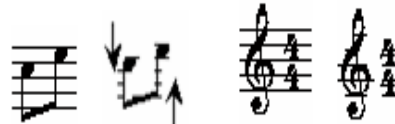


Fig. 2 Under-removal phenomenon

is brought up, at first, trajectory tracking of staff line approach is utilized to pre-delete the staff lines for music score, then according to the topological structure of different music notations and crossing style with staff line, further revision is executed sequentially. Experimental results show the presented algorithm can be able to solve the shortcoming of under-removal and over-removal fast and effectively.

## 2. Algorithm Description

For the mistaken deletion or over-deletion phenomenon and the under-removal phenomenon which exist in subsection approach universally, trajectory tracking removal algorithm pointwisely is put forward to solve under-removal problem, for the over-removal problem, by carefully analyzing the removal results utilized the approach advanced above, there are main two cases or analogously which exist over-removal problem and affect the subsequent segmentation and recognition, representing at one connected symbol divided into more than two unconnected parts, shown as Fig. 1, else cases can't influence the segmentation and recognition though partial segmentation is deleted in the process of staff line removal, but still are a part, shown as Fig. 3, so, those symbols don't need revision painstakingly. As a sequence, a removal algorithm based on topological structure of music symbols is put forward to revise for the mistaken-deleted symbol by analyzing the structure characteristic of related music symbols and summarizing its rule. As a result, better removal performance can be achieved.

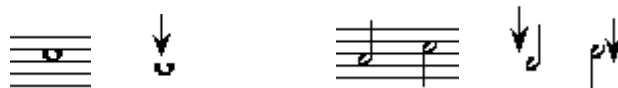


Fig. 3 music symbols which are be deleted but don't affect segmentation and recognition

In fact, trajectory tracking removal algorithm pointwisely is simple, namely judge whether the upper of the lower one pixel of each staff line is black pixel or not, if exist, then the staff line is deleted unless the whole image is handled over, unlike subsection removal approach, here, staff line is removed pointwisely to avoid the under-removal phenomenon, then revision operation on the image which have deleted the staff lines is implemented, particular algorithm is described as follows:

1) According to the result of staff line detection, record the row positions of all the staff lines

$Pos(m), m = 1, 2, \dots, N$ , where  $N$  is the row number of staff lines.

2) Along staff line direction, search the upper or the lower one pixel and distinguish which is black pixel or not, for each staff line, if yes, then the existence of crossing or overlapping between music symbols and staff line is confirmed and the staff line point reserved, otherwise deleted.

$$\begin{cases} B(k, y) = 0 & B(Pos(m) - 1, y) = 0 \mid B(Pos(m) + 1, y) = 0 \\ B(k, y) = 1 & \text{else} \end{cases}$$

3.1

Where  $1 \leq y \leq W$ , is the column of image,  $k = Pos(m), Pos(m) + 1, \dots, Pos(N) + xk - 1$ ,  $xk$  is the row label number and thickness of each staff line respectively.

3) Record the row and column position of non-deleted black pixels as  $P(n, 2), n = 1, 2, \dots, num$ ,  $num$  is

the number of non-deleted black pixels, and calculate the length of vertical black run-length which the non-deleted black pixels are belong to,  $yc(n), n = 1, 2, \dots, num$ .

4) Begin with the first black pixel which doesn't be deleted, if the adjacent black pixels meet: 1) located at the same row, 2)geometric distance is equal to 2 and the length of vertical black run-length which the two points are belong to isn't two times more than the staff line space, then straightly connect the two points, else go to the fifth step.

$$B(x,y)=0 \quad P(n+1,2)-P(n,2)<2 \& P(n+1,1)=P(n,1) \& yc(n) \leq 2 \& yc(n+1) \leq 2 \quad 3.2$$

Where  $x = P(n), P(n)+1, \dots, P(n)+xk-1$ ,  $P(n,2) \leq y \leq P(n+1,2)$ ,  $n$  is the label number of black pixel which doesn't be deleted to the present.

5) If the geometric distance meets the follow conditions: 1) more than 3, 2)1.5 times less than staff line space, 3)the length of run-length which two black pixels is belong to is 1.5 times less than space, 4)the adjacent pixels located on the upper position of the first one black pixel, the upper and upper-right position of the second one black pixel respectively, then the two black pixels are implemented the connection operation.

$$B(x,y)=0 \quad 3 \leq P(n+1,2)-P(n,2) < 1.5x_{jj} \& P(n+1,1)=P(n,1) \& yc(n) \leq 1.5x_{jj} \& yc(n+1) \leq 1.5x_{jj} \& B(P(n,1)-1, P(n,2))=1 \& B(P(n+1,1)-1, P(n,2))=1 \& B(P(n+1,1)-1, P(n,2)+1)=1 \quad 3.3$$

Where  $x = P(n), P(n)+1, \dots, P(n)+xk-1$ ,  $P(n,2) \leq y \leq P(n+1,2)$ ,  $x_{jj}$  is staff line space,  $n$  is the label number of black pixel which doesn't be deleted so far.

6) The number of black pixel adds one, then, go to the forth step unless staff line revision is over.

### 3. Experimental Results and Analysis

In the paper, printed music score is mainly taken as the search object. usually, before the staff line removal of music score, preprocessing such as noise removal, inclining image revision, and staff line detection should be executed. Figure.5 is a binary music score which has already been preprocessed for original input music score Figure. 4, then the next step is staff line detection, projection approaches usually



Fig. 4 Original input music image



Fig. 5 Binary music image after preprocessing

are applied in the stage, mainly because of fast speed and simple algorithm. Figure 6 is the vertical project graph for the binary music score, according to the project image, the position of staff lines can be detected. Here, three removal algorithm for staff line removal, namely, staff line track removal algorithm, run-length group slices, and the presented algorithm are executed to the input music image, the removed music image are shown as Figure 7(a), (b), (c) respectively.

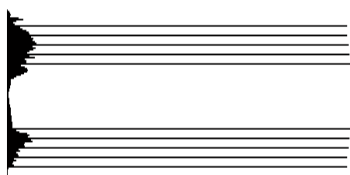


Fig. 6 Vertical project graph staff for the binary music score



Fig. 7 (a) removal result of conventional line track removal approach



Fig. 7 (b) removal result of  
run-length graph slice method



Fig. 7 (c) removal result of the  
algorithm advanced here

According to the experimental results, conventional staff line track removal approach can lead to mistaken removal or over-removal phenomenon, making some connected symbols become more than two symbols after staff line removal to arouse mistakes in the next segmentation, influencing the recognition rate of music symbols and score reconstruction. Run-length graph slice method can avoid the phenomenon of mistaken removal at certain content, however the problem of under-removal may occur, in some cases, two independent symbols are connected because of short of removal, like the former, affecting the next processing of OMR. But the algorithm which is put forward in the thesis can solve mistaken removal or over-removal problem effectively, those parts which should be deleted or not can be removed or reserved accurately. As a consequence, the operation efficiency of subsequent segmentation and recognition can be improved remarkably.

## 4. Conclusions

Staff line removal is the precondition of segmentation and recognition of music symbols, for the faults of over-deletion or mistaken deletion and under-deletion problem which often appear in removal process of staff lines, an algorithm based on trajectory tracking and topological structure of music symbols is put forward to solve, firstly, trajectory tracking removal approach is adopted to solve under-deletion problem, then revised algorithm based on topological structure of music notions is brought forward to solve over-deletion or mistaken problem, combining the two approaches can solve the faults in the process of staff line removal effectively, moreover, the integrality and independency of music symbols can be guaranteed. Experimental results show the validity and practicality of the presented algorithm and realize the staff line removal object fast and effectively.

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