Vietnamese-German University

MUSIC SHEET UNDERSTANDING AND TRANSPOSITION

July 23, 2021

Contents

I Research team members

- Team Leader: Truong Minh Khoa
- Programmer: Dinh Cong Minh
- Programmer: Nguyen Tho Anh Khoa
- Writer/Editor: Huynh Minh Triet

II Disclaimer

This report is a product of our team's work, unless otherwise referenced. In addition, all opinions, results, conclusions, and recommendations are of our own and may not represent the policies or opinions of the Vietnamese-German University's Department of Engineering or the University as a whole.

III Abstract

IV Introduction

The topic of recognizing musical sheets, i.e., Optical Music Recognition (OMR), is not a novel field of research. The term OMR first appeared in a paper written by MIT scientists in the 60s. During the last three decades until now, OMR is an ever increasingly developing field and is capable of solving many problems that involves with music

More specifically, the current OMR systems of today are capable enough to recognize a printed musical sheet and digitize it. The resulting output could be a .midi file, or other types of sound files such as .way, .mp3. The vast majority of those researches are dedicated for the common user, even for users who are not educated on musical theory, but there is still a lack of product that can be used for professional or enthusiast musicians. In reality, a common problem that is encountered is the transposition of music tones, i.e., up or down semitone, tone for the whole music sheet. Currently in order to obtain a music sheet with a few tones higher or lower the musicsian has to manually retype the entire musical sheet by hand, which is labor intensive.

i Our solution

We propose an algorithm that can take in a pdf file or scanned music sheet, then translate the written note either by hand or computer drawn into scientific pitch notaion [3]. At which stage, the program can play the song or shift the song's tones or semitomes according to the musicians' need.

V Proposed Method

The process include first removing the lines on each staff for ease of musical note dectection. The second stage is translating the detected note and do note recognition to translate notes into a digital format. Finnaly the last stage is where an additional python function will modulate the tones of the song to give the final output.

i Line Removal

By using the method in Gomez and Sujatha [1] the staff's line removal algorithm will first grayscale the image then invert the color of the image, so that the lines are now white and the background is black. Finally, using a kernel of the form:

$$\begin{pmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 0 & 0 & 0 \end{pmatrix}$$

then run with the dilate() function built-in OpenCV, the horizontal lines will be expand so that its width is increasingly larger, and any white pixels, i.e., notes, that does not belong to the horizontal line, will be flipped to 0 and becomes the background thus eliminating notes.

result:

(a) music sheet before line removal

(b) music sheet after line removal

Finally, flipping the output image will result in a music sheet with lines removed:

ii Note Translation

In order to translate the note its input as pictorial data to a digitalized form so computer can process the music sheet, three steps are required. First by using Rosebrock [2] method to eliminate overlaping note positions. Second is to reorder the notes that are on the same staff lines into a list, for each staff line there is a corresponding list containing the positions of each note on that staff. Finally, converting the note positions into musical note notation.

Eliminating overlaping positions

By running template matching on the output music sheet that is removed of staff lines will obtain a list of position of notes on said music sheet. However, there is a problem with multiple note positions overlapping each others.

Inorder to handle this we use Rosebrock [2] method call Faster Non Maxium Supression so that each note will only have one position entry, avoiding duplication in our list of note positions.

Note reordering

Next musical notes that belongs to the same staff will be grouped into the same list, for each staff line there is a corresponding list containing its note. In order to do this, from the position of first line(the bottom line of each staff) move down for a distance of half a staff height and then create a second point which is from the current point up two staff heights [1]. Any note's vertical position that fell in the range from those previously mentioned point will be considerd as in the same staff line

In musical sheet if two staves are connected with a curly bracket on the left meaning they must be played simultaneously.
E.g:

In the example above the staff above with the treble clef is called the main staff and the staff below with the bass clef is called the sub staff. The algorithm will now initialize two list MAIN[] and SUB[] to store the two staves respectively.

[1] the reason for moving half of a staff height from the first line down and then moving two staff height up is to account for notes that are on the staff and the ledger line

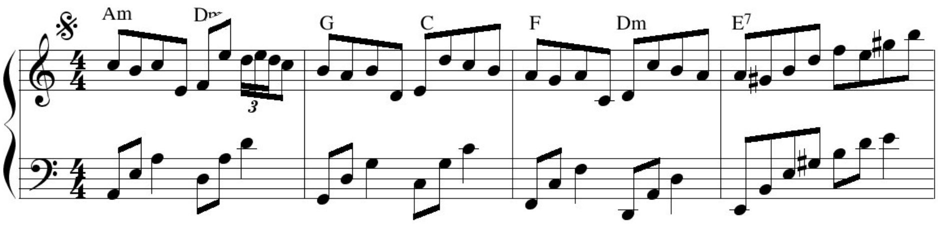

Figure 2: Two staves that need to be played simultaneously

Now the algorithm will move simultaneously through both staff and check the notes iteratively. For example our first note MAIN[0] and SUB[0], if they are vertically aligned, meaning that it need to be play simultaneously, the alogorithm will then move MAIN[0] and SUB[0] to MAIN_RE_ORDERED and SUB_RE_ORDERD. By move the algorithm will cut the note position from the original MAIN list and paste it into the MAIN_RE_ORDERED, same goes for SUB_RE_ORDERED.

However since some music sheet has minor error in printing resulting in minor misalignment of the note, meaning they are still supposed to be play simultaneously but their horizontal (x axis) position are not exactly the same. The function ReoderedStaffs() has a threshold value of 5, meaning if the two notes deviate from each other, either to the left or right, less than 5 pixels we will consider that they will be played simultaneously.

If there is a case, where there is only one note on one of the staff, meaning only one note need to be played at that moment, we will add the tuple (0,0) into the staff that doesn't have a note as a filler note. In the case that any staff ran out of note before the other staff, we will continue the moving process like normal, but will fill in elements (0,0) for the ran out staff. Doing this assure that the two list MAIN_RE_ORDERED and SUB_RE_ORDERED will always have the same number of elements in their list.

This is the result of the first five notes of the two staves in figure number 2

```
(216, 253), (242, 260), (270, 253), (298, 285), (325, 278)
(216, 412), (271, 368), (298, 381), (0, 0),     (353, 368)
```

Figure 3: The fourth position has a (0,0) tuple because there is no corresponding fourth note on the sub staff

Digitalization of the notes

With the list of notes's position, to be able to make note transposition possible they need to be translateed into musical notation.

To achieve this we have create four lists containing scientific pitch notaion [3]. two list for the main staff and two for the sub staff(one for notes above the first staff line and one for notes below the first staff line).

The two list for the main staff:

['E5','D5','C5','B4','A4','G4','F4','E4','D4','C4','B3','A3','G3','F3','E3','D3','C3']

Figure 4: notes below the first staff line of the main staff

['E5','F5','G5','A5','B5','C6','D6','E6','F6','G6']

Figure 5: notes above the first staff line of the main staff

The two list for the sub staff:

['G3','F3','E3','D3','C3','B2','A2','G2','F2','E2','D2','C2','B1','A1','G1','F1','E1']

Figure 6: notes below the first staff of the sub staff

['G3','A3','B3','C4','D4','E4','F4','G4','A4','B4']

Figure 7: notes above the first staff line of the sub staff

Whenever a note is encountered on the staff line, a number will be generate which will be used as index to get the note notation. But since each staff has two list which can be choose from. This problem is resolved by the following formula:

$$D = \frac{2.(note\_position[1] - headlines[i])}{d}$$

D is the ouput
note_position[1] is the veritcal position of the note
headlines[i] is the position of the first staff line of each staff
d is the distance between two staff lines in a staff [2]

[2] the full equation is: $D = note\_position[1] - headlines[i]/d/2$ with d/2 divided by two because each note is separated with just half of the distance between each staff lines

If D < 0 the algorithm will use the list for notes below the first staff line and D ≥ 0 will use the list of notes that are above the first staff line.

$$I = \begin{cases} \text{D}, & \text{if } D \geq 0 \\ \text{-D}, & \text{otherwise} \end{cases}$$

Continue to repeat this staff by staff for all staves in the music sheet will result in a list of notes in the music sheet orgainized in chronological order.

iii Tones transposition

After the previous process the output is a list of scientific pitch notaion [3], e.g., C3, B2, C3, E2, F2, E3, D3, C3.

In music theory shifting a musical note up or down a tone or semitone follow a predictable pattern:

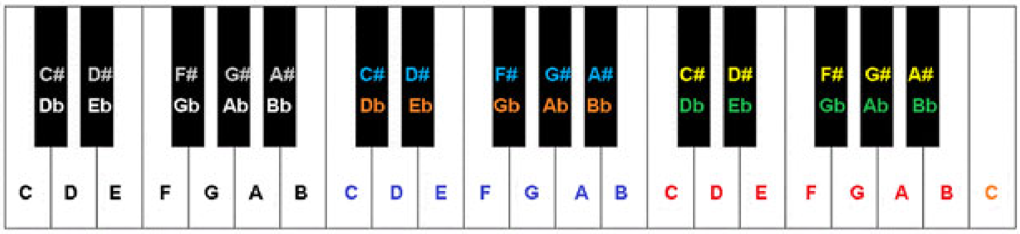

Figure 8: layout of a piano keyboard

According to the graph above, the music note C3 shifted up a tone would become C#3, same goes for all other note, they become a sharp note. Except for the note E and B which when shifted up a semitone becomes F and C respectively.

To solve this problem we create a list of scientific pitch notaion arrange in increasing order similar to figure 8.

notes_height= ['E1', 'F1','G1','A1', 'B1', 'C2','D2', 'E2', 'F2','G2','A2', 'B2', 'C3', 'D3', 'E3', 'F3','G3', 'A3', 'B3', 'C4', 'D4', 'E4', 'F4', 'G4','A4','B4', 'C5', 'D5', 'E5', 'F5', 'G5', 'A5', 'B5', 'C6', 'D6', 'E6', 'F6','G6','A6','B6' ,'C7','D7', 'E7', 'F7','G7','A7', 'B2',]

```
if(chord.name!="E" and chord.name!="B" and chord.sharp==False):
    chord.sharp = True
else:
    chord.sharp = False
    chord.name +=1  # E + 1 = F, F+1 = G, etc
```

Bibliography

[1] Ashley Antony Gomez and C N Sujatha. "Optical Music Recognition: Staffline Detectionand Removal". In: 6.5 (2017), pp. 48–58.

[2] Adrian Rosebrock. *(Faster) Non-Maximum Suppression in Python - PyImageSearch*. URL: `https://www.pyimagesearch.com/2015/02/16/faster-non-maximum-suppression-python/`.

[3] Wikipedia. "Scientific pitch notation". In: *The Free Encyclopedia Wikipedia [web page]* (2013). URL: `https://en.wikipedia.org/wiki/Scientific%7B%5C_%7Dpitch%7B%5C_%7Dnotation%20http://en.wikipedia.org/wiki/Scientific%7B%5C_%7Dpitch%7B%5C_%7Dnotation`.