# **Automated Arrangements of Multi-Part Music for Sets of Monophonic Instruments**

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Arranging music for a different set of instruments that it was originally written for is traditionally a tedious and time-consuming process, performed by experts with intricate knowledge of the specific instruments and involving significant experimentation. In this paper we study the problem of automating music arrangements for music pieces written for monophonic instruments or voices. We designed and implemented an algorithm that can always produce a music arrangement when feasible by transposing the music piece to a different scale, permuting the assigned parts to instruments/voices, and transposing individual parts by one or more octaves. We also published open source software written in Python that processes MusicXML files and allows musicians to experiment with music arrangements. It is our hope that our software can serve as a platform for future extensions that will include music reductions and inclusion of polyphonic instruments.

CCS Concepts: • Applied computing → Sound and music computing.

Additional Key Words and Phrases: music arrangement, music algorithms

#### **ACM Reference Format:**

#### 1 INTRODUCTION

Music arrangements involve the adaptation of a piece of music for different instruments or ensembles. This allows the music to be performed in a variety of settings, enhances the repertory of musicians, and can also help to bring new life to a piece that may have been composed for a specific instrument or ensemble [16]. Additionally, arrangements can help to showcase the unique strengths of different instruments or even create entirely new interpretations of a piece. The process of arranging a piece of music can be a creative endeavor in itself, giving the arranger the opportunity to put their own spin on a familiar work, greatly enhancing the listening experience for audiences [1, 5, 12].

The computational complexity of arranging music written for a set of instruments toward a target single instrument, often employing reasonable reductive constraints, has been examined in the work of Moses and Demaine [4]. Complexities of dealing with polyphonic instruments, such as piano and guitar, include the need of considering possible fingerings as well as reductions, the elimination of certain notes for playability of even feasibility. Most research in automating music arrangements has concentrated on the piano, primarily concerning orchestral pieces [2, 8, 10, 11, 13, 14]. Much of that work involves reductions to enable feasibility. Other work in the field has examined arrangements for the guitar [6, 7, 15], wind ensembles [9], and other orchestral instruments [3].

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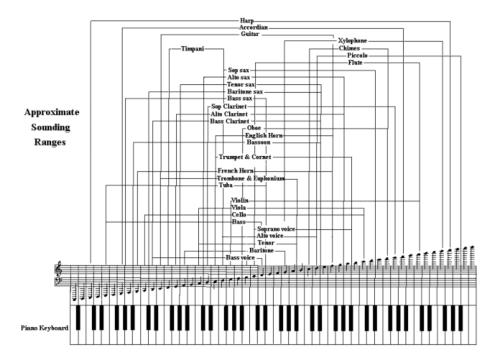


Fig. 1. Approximate sounding ranges of instruments and voices. Figure reproduced with permission from Dr. Brian Blood (dolmetch.com)

Despite its obvious benefits, we are not aware of any published algorithm or widely available software that allows for the automated arrangement of a given music piece to a different set of instruments that it was originally written for in the general case. Working toward filling that need, we designed and implemented an algorithm that arranges music written for monophonic instruments and guarantees a successful outcome when an arrangement is possible without score reduction. Our recursive backtracking algorithm exhaustively examines all feasible assignments of parts to available instruments and all possible transpositions of the piece, including independent octave transpositions of individual parts, to determine a successful arrangement that minimally affects the musicality of the piece.

### 2 METHODS

#### 2.1 Definitions

For the purposes of our research, a music piece is written in a chromatic scale and notes are separated by the interval of a semitone. We will assume that all notes fall within a total range of 88 semitones, the notes of a traditional piano, from A0 to C8. We will assign an integer to each note in the range, such that all notes can be represented by an integer from 1 to 88. For our discussion, a monophonic instrument is one that can only play one pitch at a time, such as the flute, the oboe, or a voice. Polyphonic instruments can play multiple notes simultaneously, such as the piano, guitar, or harp. A polyphonic instrument can always play a monophonic part within its range.

For our study an input music piece will consist of n parts, each being assigned to a single monophonic instrument or voice. Such parts are presented in the sheet music representation of the piece in an equal number of staves each. Our Manuscript submitted to ACM

Fig. 2. Examples of input instrument set and instrument information files

algorithm preserves the rhythm, rhythmic values of notes and rests, as well as bar lines of the music piece. Clefs, key signatures and accidentals are adjusted based on the scale of the transposed music and the instruments/voices that parts are assigned to. Our algorithm does not control for instrument timbre that may be expected in any part of the music; similarly, the thickness of the piece is not being necessarily maintained.

We will assume that an input music piece is originally written for n instruments  $I_1, I_2, \dots, I_n$ , each assigned to play a part  $P_i$  of the piece, with  $1 \le i \le n$ . We seek to arrange the music for n output instruments  $O_1, O_2, \dots, O_n$ . The range of each part i is an integer interval  $R_i = [\![a_i, b_i]\!]$ , where  $a_i$  is the integer value corresponding to the lowest frequency note and  $b_i$  to the highest frequency note played by instrument  $I_i$  in part  $P_i$ ,  $1 \le i \le n$ . Likewise, the playing range of each output instrument  $O_i$  will be denoted by  $OR_i$ ,  $1 \le i \le n$ , indicating the integer interval of values corresponding to the notes the instrument is able to play. Approximate ranges for a set of instruments and voices can be seen in Figure 1.

# 2.2 Monophonic instrument set arrangement algorithm

Our Monophonic Music Arrangement (MMS) algorithm performs a nearly comprehensive search of possible permutations of parts. The music is transposed to all twelve keys, and the algorithm runs on each key, unless a solution has been found so far that results in fewer sharps/flats over all keys for each part. This is designed to prevent the "ideal" transposition from having a complex key signature if not necessary. Other than that, the search is fully comprehensive. For each part, the algorithm finds all possible transpositions of each part in the source piece that can be played by at least one available instrument. All permutations of these possible transpositions are then examined. If all parts can be played by at least one instrument, the algorithm then checks if there exists a set of part assignments that is valid. This is performed by a recursive function that is memoized to improve performance. If a transposed key yields valid permutations, the transposition with the least total deviation from the original composition is selected. Once all twelve keys have been checked, all permutations are tried using the selected transposition, unless there is no selected transposition, in which case the algorithm fails. All permutations are checked, and for those that are valid in the given transposition, the best arrangement is selected based on how closely the average pitch of each part matches the median pitch of the instrument's range.

The MMA algorithm implementation consists of four main function described in pseudocode below.

## 2.3 Implementation

The MMA algorithm was implemented in Python utilizing the Music21 library and the MuseScore software. Our program requires two input files and produces a single output file with the music arrangement. The required input files consist of the original piece of music in MusicXML format and a TOML file listing the instrument set to arrange for, where an assigned value of k to an instrument indicates k parts should be arranged for that instrument. An example of a TOML file with an input instrument set consisting of one clarinet, two tenor saxophones, and two alto saxophones is  $\frac{\text{Manuscript submitted to ACM}}{\text{Manuscript submitted to ACM}}$ 

# Algorithm 1 Find Transposed Options

```
procedure FINDTRANSPOSEDOPTIONS(originalStream, arrangementParts, semitones)
   stream \leftarrow original Stream transposed by given semitones
   parts \leftarrow new list
   for part in stream do
       choices \leftarrow new list
       for each transposition do
           set \leftarrow the subset of arrangementParts that can play at this transposition
           add (semitones + transposition, set) to choices
       end for
       if choices is empty then
           return null
       end if
       add choices to parts
    end for
   return parts
end procedure
```

#### Algorithm 2 Run Transposed

```
procedure RunTransposed(stream, parts, semitones)
   selections \leftarrow new list
   for option in all possible transpositions from FINDTRANSPOSEDOPTIONS(stream, parts, semitones) do
       partsCovered \leftarrow new list
       selection \leftarrow new list
       for transposition in option do
           add set of parts covered to partsCovered
           add deviation of transposition to selection
       end for
       allPartsCovered \leftarrow the union of all sets in partsCovered
       if allPartsCovered contains all parts and ValidateArrangement(parts, partsCovered, allPartsCovered) then
           add selection to selections
       end if
   end for
    return selections
end procedure
```

shown in Figure 2a. Metadata about each instrument, consisting of its key in notation and a reasonable note range, is defined in a separate TOML file which is loaded separately by the program and is populated with common music instruments. An example of an entry for the alto saxophone in the instrument metadata file is shown in Figure 2b.

During execution our program checks whether the number of input instruments matches the number of parts in the piece, and then attempts to arrange for the given instruments as previously described. If arrangements are found, the best arrangement based on the criteria described in section 2.2 is output as a MusicXML file. If no feasible arrangement is found, or if the number of instruments does not match, then an error message is displayed and no output file is produced.

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# Algorithm 3 Find Best Choice

```
procedure FindBestChoice(stream, parts)
   bestChoice \leftarrow null
   bestSharps \leftarrow \infty
   for semitones from -6 through 5 do
       sharps ← the total number of sharps/flats that would appear in the key signature for each part
       if sharps \le bestSharps then
           thisBestChoice ← element from RunTransposed(stream, parts, semitones) with the least deviation
           if thisBestChoice ≠ null and either sharps < bestSharps or deviation of thisBestChoice < deviation of
bestChoice then
              bestChoice \leftarrow thisBestChoice
              bestSharps \leftarrow thisBestSharps
           end if
       end if
   end for
   return bestChoice
end procedure
```

# Algorithm 4 MMA Algorithm

```
procedure MMA(stream, parts)
   bestChoice ← FINDBESTCHOICE(stream, parts)
   if bestChoice = null then
       return null
   end if
   transpose each part by the resulting transposition
   bestFit \leftarrow \infty
   for each permutation of newParts do
       if all parts are valid in the given permutation then
           fit \leftarrow the total absolute difference between the average pitches and the median pitch of each part
           if fit < bestFit then
               bestFit \leftarrow fit
               bestPermutation \leftarrow this permutation
           end if
       end if
   end for
   return bestPermutation
end procedure
```

# 3 RESULTS

We tested our software on a variety of music pieces written for monophonic instruments. In Figure 3 we show three measures, starting at measure 16, of the *Puttin'* on the *Ritz* song by Irving Berlin. Part (a) shows the input score composed of four monophonic parts. Part (b) displays the arranged piece for saxophone quartet, consisting of a soprano, alto, tenor, and baritone saxophones. Similarly, in Figure 4 we display three measures of *Carol of the Bells*, as arranged and performed by the Pentatonix voice group, starting at measure 18 of the piece.

Complete input/output files for three test cases of our software, including the *Puttin'* on the *Ritz* and *Carol of the Bells* above, can be examined at: https://owd.tcnj.edu/~papamicd/music/mma/examples/

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The repository for this project can be found at: https://github.com/spazzylemons/music-arrangement/

# 4 CONCLUSIONS AND FUTURE WORK

Our monophonic music arrangement algorithm and its software implementation create a platform for automating music arrangements with minimal user input. Although currently basic in its functionality, it can be readily extended in a number of different directions. For accommodating arrangements for a smaller sets of instruments than the number of parts in the music, score reduction techniques can be applied to eliminate certain parts or at least reduce the number of simultaneous notes that are played throughout the piece, while maintaining faithfulness to the original. To allow for the inclusion of polyphonic instruments in the arrangements, further work is required in analyzing and decomposing

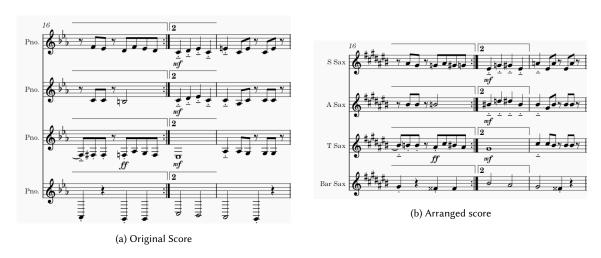


Fig. 3. Three measures from an arrangement of 'Puttin' on the Ritz' from piano to saxophone quartet

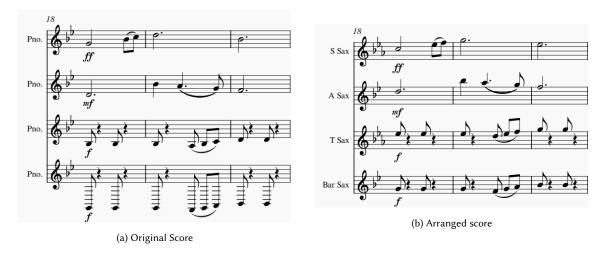


Fig. 4. Three measures from an arrangement of 'Carol of the Bells' from voices to saxophone quartet Manuscript submitted to ACM

polyphonic parts into monophonic ones and inversely, while adhering to constraints related to fingerings and other instrument and player restrictions.

#### **ACKNOWLEDGMENTS**

The authors acknowledge use of the ELSA high performance computing cluster at The College of New Jersey for conducting the research reported in this paper. This cluster is funded in part by the National Science Foundation under grant numbers OAC-1826915 and OAC-1828163.

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