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DAMUS: A COLLABORATIVE SYSTEM FOR CHOREOGRAPHY AND MUSIC COMPOSITION

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ABSTRACT

Throughout the history of dance and music collaborations, composers and choreographers have always engaged in separate workflows. Usually, composers and choreographers complete the music and choreograph the moves separately, where the lack of mutual understanding of their artistic approaches results in a long production time. There is a strong need in the performance industry to reduce the time for establishing a collaborative foundation, allowing for more productive creations. We propose DAMUS, a work-in-progress collaborative system for choreography and music composition, in order to reduce production time and boost productivity.

DAMUS is composed of a dance module DA and a music module MUS. DA translates dance motion into MoCap data, Labanotation, and number notation, and sets rules of variations for choreography. MUS produces musical materials that fit the tempo and rhythm of specific dance genres or moves. We applied our system prototype to case studies in three different genres. In the future, we plan to pursue more genres and further develop DAMUS with evolutionary computation and style transfer.

Index Terms— choreography, music composition, collaborative system

1. INTRODUCTION

We present a work-in-progress project named DAMUS, a collaborative modular and data-driven system that aims to algorithmically support the composers and choreographers to generate original and diverse development for their creative variations and continuities. The project name DAMUS means “we offer” in Latin. Meanwhile, it is also a combined terminology with DA, the dance module, and MUS, the music module. Conventional dance-music collaborations regularly take a significant amount of time for collaborators to adapt to one other’s creative languages; occasionally, collaborations can become overly exclusive, resulting in collaborations between only certain artistic groups. Nowadays, fast-paced productions and more inclusive creative collaboration environments necessitate an efficient solution that can preserve a significant amount of artistic authenticity while also facilitating rapid “brainstorming.” DAMUS, the compound collaborative authoring system, aims to build a collaborative foundation for choreographers and composers through algorithms. Using DAMUS will reduce time consumption on communication and motivate dynamic expressions by treating their complete or scattered creative ideas as preliminary units. We leverage machine learning, evolutionary computation, and creative constraints to produce dance and music variations either for a single user or for multiple users, where they can interact with each other and express themselves dynamically. We will present details of our system design, data collection, the DAMUS components (the dance module and the music module), as well as the underlying logic for each. Furthermore, we would like to share our preliminary creative outputs through case studies involving three distinct dance genres: ballet, modern dance, and Chinese Tang Dynasty dance.

2. RELATED WORK

Choreography. Many have explored how algorithms and machine learning could engage with choreography. Since the 1960s, Merce Cunningham applied new computer software and motion capture technology to choreograph dance in a brand new way [1]. The experimental work by Michael Noll also generated basic choreographic sequences from computers [2]. Some scholars studied choreography from a semiotic aspect and invented dance notations that maintain the authenticity of choreography, which could be further processed into dance learning, practice and research, e.g. Labanotation, Benesh Notation, and Eshkol Wachman Notation. For example, the Microsoft Labanotation Suite [3] can perform translation between MoCap skeleton and Labanotation, which enables robots to learn to dance from observation.

Music Composition. Algorithmic composition has had a long history for hundreds of years [4]. With the development of technologies used in the art field, people have started to apply more advanced programming methods to music composition to support creative purposes. For example, the HPSCHD system established by computer scientist Lajaren Hiller for composer John Cage, which is influenced by chaos theory, assists in making music elements move away from unity [5]. Another example is OpenMusic, a visual programming language for computer-assisted music creation developed by Tristan Murail and his team to support the development of spectral-based calculations in music composition. It enables interesting mathematical algorithms to provide fascinating sonic outcomes [6]. The third example is MaxMSP, which provides basic Markov Models and generative grammars for music creators to generate their ideas.

Dance-Music Interaction. Recent advances in algorithms have also enabled dance synthesis from music data. For example, by analyzing the beats and rhythms in a video, researchers can create or manipulate the appearance of dance for better synchronization [7, 8]. State-of-the-art datasets like AIST++ and deep learning architecture like transformers also pushed the boundaries of dance synthesis, producing realistic dance motions matching the input music [9, 10].

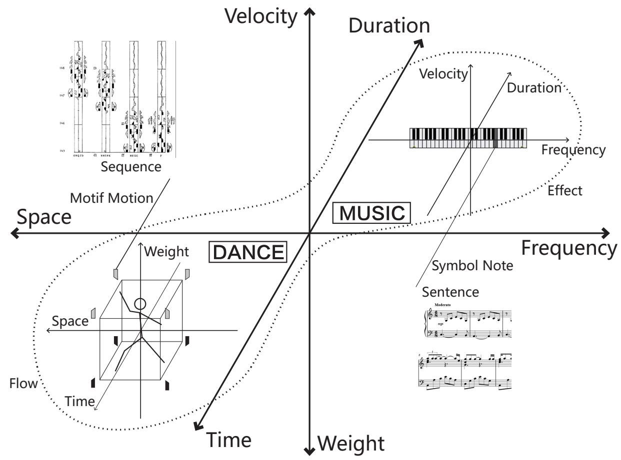

Fig. 1. Corresponding elements in dance and music.

3. SYSTEM DESIGN

DAMUS is based on the corresponding relationship between dance and music: space and frequency, time and duration, weight and velocity, flow and effect (Fig. 1).

The inputs of symbols and notes will be analyzed as creative constraints. Based on motion pattern selection and mapping pattern execution, with further evolutionary computation and style transferring, DAMUS will generate new variations of dance and music pieces as a foundation for collaboration. Artists could then manually select the ones they want (Fig. 2).

This system can be jointly used by multiple users, or by a single user and another media resource in the system.

4. METHODOLOGY

4.1. Dance Module

4.1.1. Encoding Relationships

The first step is to translate a human figure to an abstract notation system. We can get an animated skeleton from the MoCap of human figure dancing, and map it to Labanotation through Microsoft Labanotation Suite, where we further highlight 13 body parts and joints. This process could also be done by a trained dance notator, and scholars have created a bunch of Labanotation documents on performances in the past century. In Labanotation, each body part is drawn onto a specific column, and we can set an encoding execution to create a number notation sheet, noting each of the body parts at a specific time (Fig. 3).

4.1.2. Algorithm-Based Re-Choreography

As the performance (musical) piece could be cut into paragraph, sentence, bar, beat, timecode (e.g., 1/2 beat), and the dance notation and music notation aligns timely, we decompose the Labanotation into timecodes with specific composition of body part condition. For simplicity, we include 27 still directions and 16 turns. In this way, the composition of the condition of each body part at each timecode is written as a series of 13 numbers with a 2-digit number. This could be transformed into a number notation sheet, a sequence of 13-dimension vector for machine learning, or a sequence of point clouds for visualization (Figs. 4 and 5).

For a specific piece of performance and based on the expression of symbolic Labanotation and its encoding, we could find some patterns of motion elements as $P_1, P_2, ..., P_m$, and a series of codes of alternation could be generated as $M_1, M_2, ..., M_n$. Some simple M's come to our mind: mirroring, alternating the step combination when the upper body shares the pattern, alternating the arms when the step combination shares the pattern. Derived from comprehensive dance research and manually picked P's and M's, we will develop algorithm to generate more M's, i.e., keeping the same motif with change in speed and rhythm. At the same time, algorithm will make the decision on the allocation of various mappings applied to the patterns.

4.1.3. Visualization of the Re-Choreography

After the variation process is applied, we need to find out a strategy to visualize the re-choreography. One way is to apply the reverse process from symbolic Labanotation to number notation sheet in Fig. 3. A trained dance notator or scholar could read the Labanotation and dance it right out. Another way is to communicate our algorithm with the Microsoft Labanotation Suite, through which the variated Labanotation could be translated into an animated skeleton or character, and a dancer could follow the animation and practice.

4.1.4. Next Steps

In a nutshell, the strategy of working with a single piece involves finding motion patterns (P's) in symbolic Labanota-

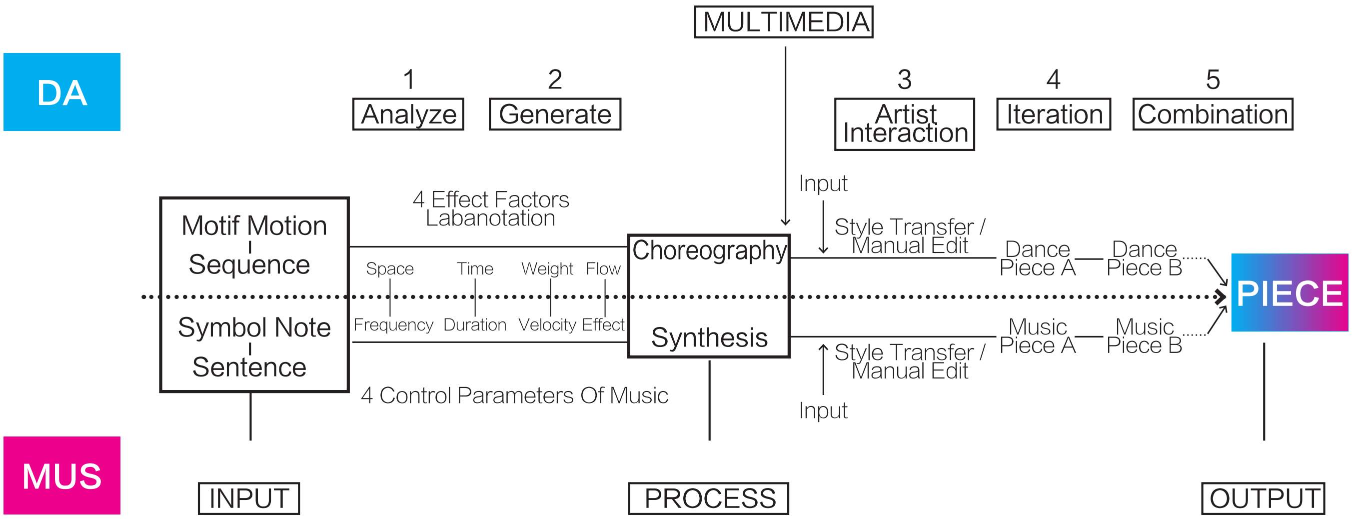

Fig. 2. System design of DAMUS.

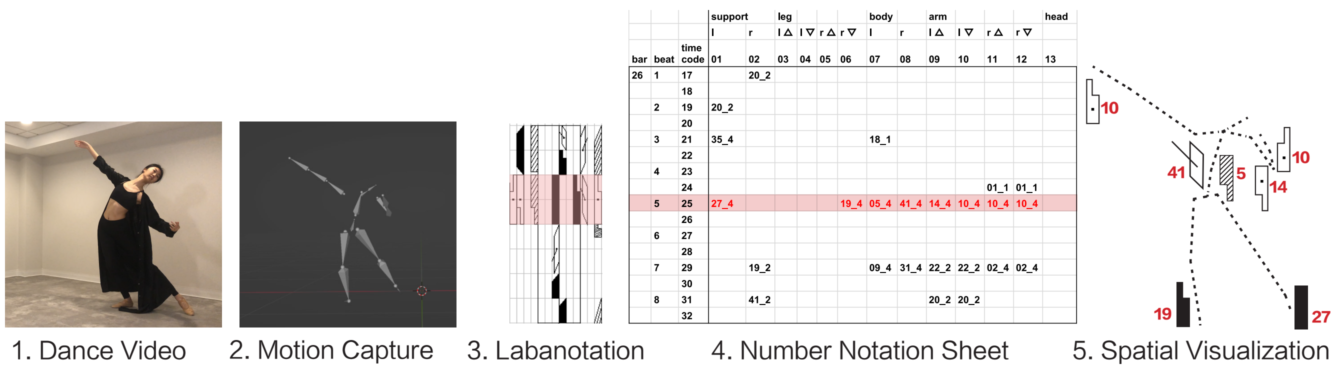

Fig. 3. Digitization process of dance moves. For example, code 10 on the right hand in the spatial visualization indicates that the dancer should move the right hand forward.

tion as well as number notation sheets, and setting mapping patterns of choreography alternation (M's). When working with a series of performance pieces of similar style, era or creators, the patterns of motions and mappings could be collected together as a dataset, and a compounded algorithm could be applied to select and create new codes from the pool.

We will also add more conditions and randomness to the algorithm for a better computational outcome. Also, solid dance research on specific motion patterns would also benefit the style maintenance during the process of mapping variations. Further on, we consider inviting the original creator or dance groups of the pieces to test the alternated choreography, and iterate afterwards.

4.2. Music Module

In traditional dance music collaborations, choreographers frequently share with the composer specific pieces of music that they have previously used as sources of inspiration for future compositions. This method, however, is frequently unproductive, particularly in new creative teams or when the composer lacks experience producing music for dance. It is also difficult for the composer to rapidly grasp the choreographer's vision, and the resulting composition commonly deviates significantly from the dance's required rhythms. If we would like to solve this issue, we need to make sure the music module can produce musical materials that fit the tempo and rhythm of specific dance genres or moves. Therefore, the first step in developing our dance and music database has been to assess the amount of music that has its own fixed music structure and rules for specific dance genres. For example, in the history of ballet performances, baroque suite music and concerto music have frequently been used in the productions. As a result, we analyzed a large number of pieces in this genre by J.S. Bach, George Frideric Handel, and G. Philipp Telemann, the three most famous baroque composers, who also had largest num-

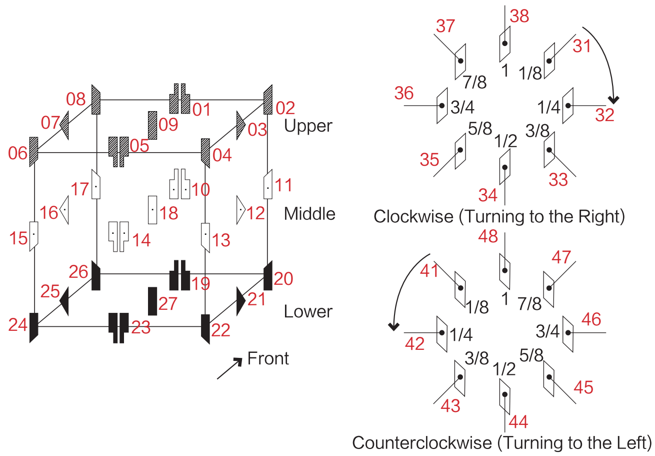

Fig. 4. Mapping 3D Labanotation to number notation.

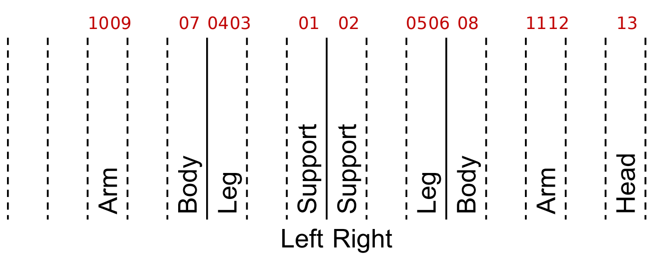

Fig. 5. Labanotation encoding for body parts.

ber of scores to digitize for training the MUS.

4.2.1. *Digitization*

The entire tempo and rhythmic model extraction process of all different music genres at this stage, starts with digitizing the score, exporting it to a midi file, transferring the midi file to a JS file, and finally extracting when and how specific music events occur over a set period of time (Fig. 6). When we come across musical pieces that we already have in our midi file collections, the progress could then begin with step three. It does not mean, the music models have to be genre specific, creators could input any possible inspiring musical score as midi or XML files into this system and analyze it as an influential elements for next step.

4.2.2. *Extrapolation and Variation*

Moreover, to make use of these influential tempo and rhythmic models the module has extracted earlier from the original sound files, the composer could either use the hidden Markov method to replace the original pitches with similar baroque music melodies, use a random pitch generator, or morph different musical pitch characters, such as installing jazz music pitches into a baroque music tempo and rhythmic models or other combinations to create fusion outcomes. This is a extrapolation progress with plenty of possibilities. After this part, the module aims reversely transferring the data from the programming stage back to the midi files and musical scores, so the creator could use the materials directly without in-depth coding experiences.

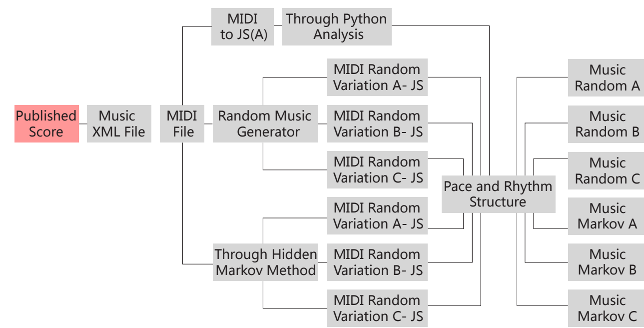

Fig. 6. Music digitization process.

4.2.3. *Next Steps*

Additionally, because the entire compound system is not intended to supplant the authors' originality, but rather to assist their needs. The next steps in our working process for the music module will be to provide as many features as possible that allow the composer to edit and influence the outcomes by adding or changing specific sound units, or by constraining the algorithm with specific criteria. For example, setting a specific key signature and pace, quantizing according to time signatures, orchestrating in specific groups of instruments, setting up basic harmonic progressions, and most importantly, relating dance movements to synchronized or non-synchronized musical contours.

5. CASE STUDIES

5.1. Database Supported Variations

The team's composer, choreographer, designer, and computer scientist have been testing the DAMUS system and trying to come up with new variables as they research. We would like to share two case studies for two different collaborative creation challenges. The first challenge that choreographer and composer team has frequently encountered is the purpose to create a new piece together which is highly referring to the existing data. Therefore, we look at two existing sets of data from our database: a complete music score, a dance score, and a performance video in the ballet and modern dance genres. These two works both employ Baroque German composer J.S. Bach's compositions as music, associating with early 20th century American dancer and choreographer Doris Humphrey's choreography as the dance part. We then try

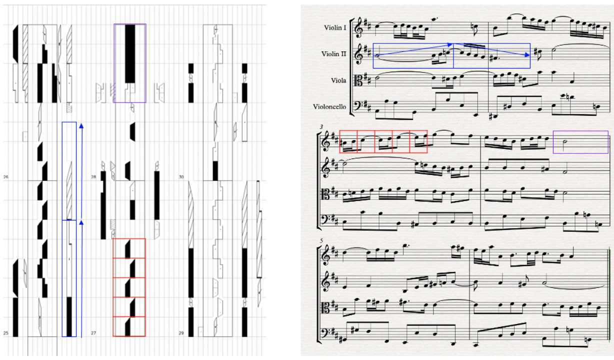

Fig. 7. Corresponding patterns in Air on the G String.

to make a different dance-music combination from the input data with a consistent pace and rhythmic model through several stages. For the music part, firstly, we extract the model as it has been addressed earlier. Secondly, we replace the original pitches with the random pitch generator among the midi notes from 1 to 127 and generate three musical pieces, which we call them random A, random B, and random C. It turns out a set of quite interesting results. Since the music is clearly atonal, the musical outcomes have been distinguishable from the original scores even though they are still two musical compositions in a rapid 3/4 pace and an elongate 4/4 pace. We believe they could be quite useful for very experimental creators, but for those who would like the musical materials close to their sources, it could be a bit problematic.

Therefore, thirdly, we replace the original pitches with the new set-up pitches that are generated from the original scores by the hidden Markov chain as Markov A, Markov B and Markov C. Additionally, we have set several counterpoint restrictions to avoid two pitches simultaneously happen in minor second, major second, minor seventh, and major seventh intervals, which against the rules of this very specific music genre. Specifically, we set functions to avoid ± 1, 2, 10, 11 midi number combinations happening at the same time.

For the dance part, the choreographic variation has been through quite different methods. The music and dance of a modern piece are always related in multiple dimensions, where deep analysis could be applied. One way is to keep the related patterns between music and dance in order to maintain the style of the original performance. For example, in Air on the G String, we have discovered several patterns, such as the elongated stretch, repeated rhythm and contour of ascending and descending (Fig. 7).

Based on the patterns of motion elements, we move to the physical variation of human bodies. Through analysis of symbolic Labanotation and its encoding, we could set mappings of variations following human kinetics and physical constraints. Take the ballet Partita as example, we name the repetitive patterns as $P_1 = \{(\text{bar}_1, \text{bar}_2), (\text{bar}_3, \text{bar}_4)\}$ and $P_2 = \{(\text{bar}_9, \text{bar}_{10}), (\text{bar}_{11}, \text{bar}_{12}), (\text{bar}_{13}, \text{bar}_{14})\}$ (Fig. 8).

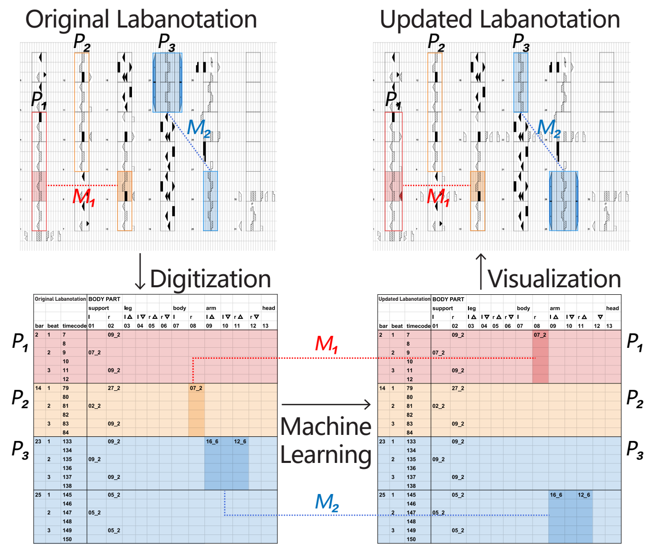

Fig. 8. Motion patterns and mappings in Partita.

Also, P_1 and P_2 have the same rhythm, suggesting the possibility of mappings between them. Here we define a possible mapping as $M_1(P_1 \leftrightarrow P_2) = \text{bar}_2[\text{body}] \leftrightarrow \text{bar}_{14}[\text{body}]$.

Similarly, we find the repetitive pattern $P_3 = \{(\text{bar}_{23}, \text{bar}_{24}), (\text{bar}_{25}, \text{bar}_{26})\}$, and we could set another mapping to switch the pairs of bars within P_3. Since the support remains the same, this mapping can be defined as $M_2(P_3 \circlearrowleft) = \text{bars}_{23,24}[\text{arm}] \leftrightarrow \text{bar}_{25,26}[\text{arm}]$.

5.2. Creative Continuation Based on Original Inputs

The second challenge that a choreographer and composer team has frequently encountered is to make variations from the raw materials they have already worked on, in order to add another section next to the existing work. In this case study, we take the Chinese Tang Dynasty dance as our genre, and first create an authentic piece without algorithms. This specific dance genre is challenging as it requires in-depth research on the ancient Chinese archives.

Nan Ge Zi is the ancient Tang Dynasty dance piece we have recovered, derived from a hand-drawn textual dance notation discovered in the Mogao Caves in Dunhuang, China, in 1900, then shipped to France by the French Sinologist Paul Eugène Pelliot and now documented in the French National Library. The study of Nan Ge Zi originated in 1930s, and now the prevailing interpretation was completed by Beijing Dance Academy in 1980s. The scholars deciphered the text into a piece of dance, and recorded it in Labanotation.

During our study, we first re-analyze the archives and renotate the dance in Labanotation based on the most updated research. Then, we create a dance-music piece with its very specific music instrumentation and dance movements to recover this historical dance as authentic as possible. After-

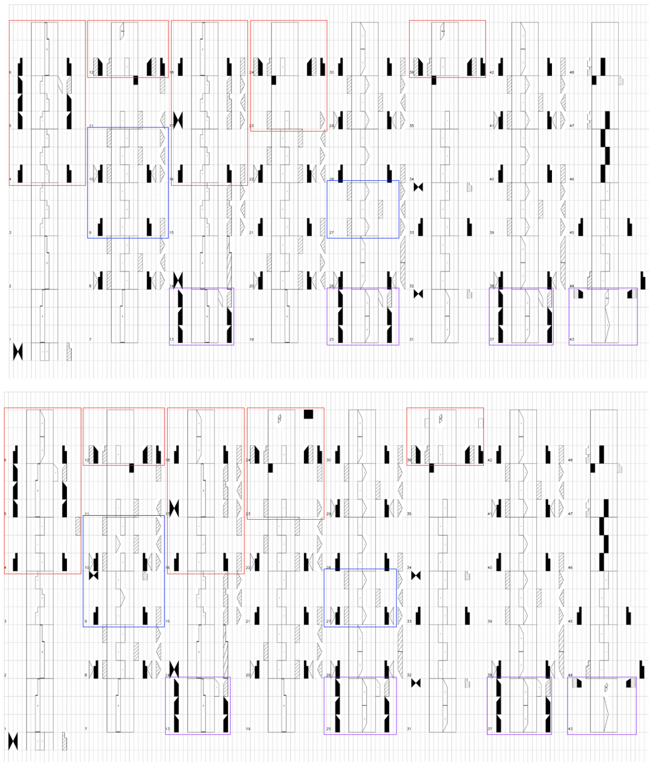

Fig. 9. Original (top) and updated (bottom) Labanotation of Nan Ge Zi.

wards, we utilize DAMUS to generate more variations.

For the dance part, since we know from the re-analysis that the piece contains eight main motion motifs, which could be elaborated into four phrases as well as 48 bars composed by 144 beats. From professional choreographers' perspective, it is reasonable to variate this continued section by changing the positions or recombine the body parts of the beats, bars or phrases with the same motif (e.g., bars 4 and 16 both describe serving wine). The figure shows the comparison between the original and the re-choreography (Fig. 9).

For the music part, the dance music in the Tang Dynasty has very specific instrument preferences, such as Pipa, Dizi, and other percussion instruments. Unlike the piano, these instruments have a limited range of pitches and require historical intonation. Therefore, when we work on the replacement of the original pitches, we carefully restrict the pitch limitation of each instrument and make sure their intonation can be either adjusted by the composer inside of the DAMUS or conveniently downloaded as a midi file and edited in other digital audio workstation (DAW) programs that composers are familiar with. So we could maintain the authentic and unified characters between the original and its continuities.

6. CONCLUSION

Based on fundamental research in dance and music, we have developed DAMUS, a system prototype for facilitating the collaboration between composers and choreographers through mapping algorithms using symbolic and number notations of dance and music. We have made the first steps on the re-composition and re-choreography methodology for ballet, modern dance, and Chinese Tang Dynasty dance. We will test more genres and further develop DAMUS with evolutionary computation and style transfer to generate new iterations of dance and music pieces as collaborative foundations.

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