



Audio Engineering Society Conference Paper

Presented at the Conference on
Spatial Reproduction
2018 August 6 – 9, Tokyo, Japan

This conference paper was selected based on a submitted abstract and 750-word precis that have been peer reviewed by at least two qualified anonymous reviewers. The complete manuscript was not peer reviewed. This conference paper has been reproduced from the author's advance manuscript without editing, corrections, or consideration by the Review Board. The AES takes no responsibility for the contents. This paper is available in the AES E-Library (<http://www.aes.org/e-lib>), all rights reserved. Reproduction of this paper, or any portion thereof, is not permitted without direct permission from the Journal of the Audio Engineering Society.

Sound-Space Choreography

Gerard Erruz¹ and Timothy Schmele^{1,2}

¹Eurecat, Centre Tecnològic de Catalunya, Multimedia Technologies Group, Barcelona, Spain

²University of Music Karlsruhe, Institute for Musicology and Music Informatics, Karlsruhe, Germany

Correspondence should be addressed to Gerard Erruz (gerard.erruz@eurecat.org)

ABSTRACT

As part of the European project BINCI, a new software tool to control sound sources in periphonic space called *Choreographer* is presented. The *Choreographer* permits to create three-dimensional source movements and work with self-curated sets of movements. Its integration inside the *Binaural Home Studio* (BHS) 3D audio production suite allows users to trigger and combine these movements in real-time performances. Parallel to the development process, the aesthetic possibilities of sound-movement have been investigated. Drawing from a review on how choreography in dance has approached aesthetic questions of movement, we discuss the relationships between working with sets of musical elements, the expressive possibilities of movement and notation. The results of this investigation have been used to present design proposals and musicologically informed features for the *Choreographer*.

1 Introduction

Since the mid-20th century, the technical possibilities for working with sound and space have evolved to the current wide range of tools for spatial audio production. Many music composers since then have adopted space as a novel parameter for their works, each using an individual approach. Consensus has not yet been reached, neither on the discursive capacities of space, nor in the meaning it can take in different scenarios. Approaches that defend facing the sound-space composition from real-world archetypes [1] contradict proposals and warnings that call for emancipation with respect to archetypes in order to avoid a premature establishment of aesthetic ideas [2]. Regarding com-

position, this paper focus on two main concepts: the emergence of form when working with sets of identifiable sound-movements, and the exploration of the expressive qualities of sound-movement by using phrasing parameters.

Recent software tools that integrate sound spatial rendering such as *IanniX* [3] or the *Choreography of sound* architecture [4] propose general and flexible frameworks for sound-space composition, with no emphasis on the control of the expressive phrasing in sound-movement. In the latter example as well as in the notation framework proposed by Ellberger et. al. [5], the possible control of sound-movements is addressed as the definition and manipulation of the mathematical

relationships between the existing sound entities. A more direct control of sound-movements, their expressive nuances and possible indications of them inside a notation system are not mentioned. As reviewed by Pérez [6], even a general lack of behavioural features is found in real-time spatialisation systems.

In the course of the development of the *Choreographer*, we have focused on providing a more direct control of individual sound-movements and its expressive nuances. We have undergone a parallel research on dance theories and their approaches to movement as the central aspect of choreographies. The qualities of movement have been largely explored by dance through its history, specially in the early 20th century, when western dance broke away from traditional ballet and started exploring movement freely. *Choreography* permits to link the creative approaches in both dance and sound. The historical dance composition approaches are analysed by focusing in two main aspects:

- The identification of the elements that will constitute the choreography and the role of movement in each particular methodology.
- The idea of what Roger Reynolds identified as the "sense of rightness": *the idea of what orderly movement is* [2]. In other words, the capacity of identifying the constituent elements of a choreography and the ability to judge them in a particular context.

The outcome of this research has been applied to improve the architecture of the *Choreographer* and to incorporate novel features that enhance the exploration of the qualities of sound-movement, both in terms of phrasing and the ways of structuring sound-space compositions. In this sense, the *Choreographer* promotes an exploration of sound-movement inspired by the historical dance choreographic practice.

The *Choreographer's* basic parameters are defined in spherical coordinates, prioritizing an egocentric approach to sound-space composition. Even so, we expect our research to be applicable to a broader set of compositional cases. Moreover, we consider the discussion in this paper to be complementary to ongoing aesthetic proposals such as the debate on real archetypes and "arena" manipulation [1], or the compositional approaches that focus on the idea of regions and places

in a specific acoustic set-up [7]. For simplification and clarity, we are not assessing these issues and we consider the idea of a neutral space around the listener.

When talking about space plainly without any additional indication, we will refer to the external, physical space, as discussed in Schmele et. al. [8]; our experience of space that is physically apart from our own bodily sensation. While sound can be perceived as being placed in periphonic space, i.e. the space "around-the-head" [9], we consider our sensation of space a product of our interpretation of our senses. As such, if we focus only on the auditory sense, space is encoded into the sound sensation that arrives at our ear. Hence, sound-space refers to not just the traditional musical spaces contained in sound such as pitch space and timbre space, but also physical space. The choreography of sound-space therefore deals with the composition of perceived sound-movements around the listener.

Because composition is closely related with notation, this paper argues for the basis on which a potential common notation in spatialised music may emerge. One major prerequisite is the existence of some instrument. In sound diffusion [10], this could be identified as the mixing desk, for which notations already exist. But, in channel-agnostic periphonic space, no dedicated tool for expressive interpretation of spatialised music exists. Hence, the *Choreographer*, as presented in this paper is a first step towards achieving this goal.

2 Dance Theory Review

2.1 Choreography

In order to analyse choreographic elements in dance and its possible transfer to sound-space composition we need to delimit the meaning of the term *choreography*. The choreographic practice is commonly associated with the orderly combination of movements that constitute a dance, this dance being usually accompanied by music. The term was coined to refer to the graphic symbols that indicate sequences of steps in a French dance treatise from 1700. This initial meaning (related to notation) was displaced to the term *choreology*, while the word *choreography* started being used in the current sense: as the art of composing dance and ballet [11]. The growing idea of dance as an art form -and not just as a social activity- contributed to the evolution and establishment of the choreographic practice. Since the beginning of the 20th century, modern dance

and later movements have challenged and broadened the classical ideas of movement and choreography. In their book *Reading Dance: The Birth of Choreology* dating from 1977 [12], Rudolf and Joan Benesh made the distinction between dance composition and choreography. They clearly separate the abstract process of extending an idea into a dance (composition) from the practical process of implementing it in an actual performance, which involve dealing with stage-craft, such as costumes, decoration and other practicalities. The latter is identified as choreography. Following this dichotomy but altering the order of the concepts, choreographer William Forsythe [13] focuses on the idea of the abstract composition of movement, identifying it as the actual choreographic practice. Furthermore, he argues that the ideas contained in a certain choreography are not necessarily linked to its enactment through a human body. Whether holding direct indications of movement or other ways of inducing it, the information that a choreography contains can be expressed in many different ways. As the traditional dependency on human body is no longer necessary, one could choreograph, as an example, the movement of a mathematical construct.

2.2 The Vocabulary of Dance

A common approach to the composition of dances is based on the identification of fixed sets of elements and the definition of relationships and hierarchies between them. *The Code of Therpsichore* [14] (1830) is a prominent example of this kind of methodology, since it helped to the establishment of the aesthetic and practical ideas of ballet [15]. Its author, Carlo Blasis, decided to elaborate the "ABC" of dance by systematically classifying poses, steps, jumps and other movements, and by regulating the relationships between these elements in a "grammar" of dance. The aesthetic ideas on the beauty of the dancing body are taken from the models in art and sculpture. In its turn, its hierarchy between poses and movements is connected to the mechanistic idea of balance. The combination between these two scales of values constructs the idea of "pure taste" [15], an idea that links with a "sense of rightness" in dance. A second example of this approach is found in the early days of postmodern dance, in the figure of Merce Cunningham. His awareness on the problematic of a totally free space led him to consider new ways of structuring time and space (especially focusing on stage space) [16]. In his work *Torse*, stage space, movement

phrases and body poses are quantized. Cunningham narrowed down the possible states of the body based on five positions of the torso and divided the stage space into a regular grid. In his own words: *Assembling these possibilities to form the phrases, the possibilities are numerous though they stay within a certain vocabulary. It's wide but strict* [17]. The choreography is then build by assembling the different elements of the vocabulary using random operations on the *I Ching*.

2.3 Harmony of Movement

Another relevant approach to dance composition appeared in the beginning of modern dance in the early 20th century: Rudolf Laban's theories on human movement, which have been later collected under the name of Laban Movement Analysis (LMA). By affirming the prevalence of movement upon the illusion of stillness, Laban elaborates a comprehensive system for describing movement and the emergence of its expressive qualities through the exploration of the space around the dancer [18]. His vision of body movement is based on an egocentric approach, and his theory is always referring to the centre of gravity of the body. When theorising dance, he organised the movements of a single dancer by defining *scales* of movement pathways. This pathways are built from the division of a virtual sphere around the dancer: the *kinesphere*. Movement in the *kinesphere* is structured by inscribing Platonic solids in it. The edges of the chosen solid and the paths between vertexes through the *kinesphere* define the available movements of the limbs. These are the building blocks, the "vocabulary" from which the dancer could start exploring movement and analysing any type of body-related action. More complex movements are build from deviations of these basic elements.

Scales of movement are built from choosing connected sequences of paths. Laban proposed that "harmonic" relationships can arise from movement paths, taking inspiration from the western music concept of the same name [19]. A clear example of this, for its similarity with the musical chords, is the combination of simultaneous movements from different body parts, which influence each other and induce expressive nuances [18]. More elaborate *dynamic qualities* are found by identifying certain directions with what Laban refers as "body tendencies" (e.g. feeling of lightness is related with the upward movement). For him, these intrinsic tendencies permit to define *scales* with a inherent dynamic richness. Each *scale* gives the dancer different

expressive possibilities that can be exploited to build larger choreographies. Apart from that, dynamics can also be performed in any desired direction. He started the development of a comprehensive system to notate body movement in time which also contains dynamics indications: the *Kinetography Laban*.

3 Notation in Music and Dance

Throughout cultures and history, notational systems have intended to capture different musical elements and were born out of sometimes entirely different approaches and concepts of music [20]. Notation is closely related with its respective music culture and as diverse as the cultures that they stem from [21]. Notation system approaches range from letter notation, over neumes, tablatures to abstract symbols, including western notes, in many types of organization in time, pitch space and articulation [20]. In modern and post-modern western notation tradition we find a departure from traditional notational systems for compositional and conceptual reasons that range from new staff systems for atonal music¹ over graphical scores² [20, 22] to purely textual instructions, as is the case with *Event Scores* in *Fluxus*. Not the sound phenomena itself should be described any more, but a direction given to the performer [22, 23]. In contrast, *Spac notation*³ is a concept that formed after the 1950, in which the temporal progression is directly represented by the horizontal space on paper [23]. Laban's *Kinematography* follows the same approach by indicating the basic time unit as a fixed time/paper space scale [24], resembling those from architectural plans.

A notated score abstracts the fixed, essential parts of the composition from its variable interpretation, depending on the available instruments of its time. Notation can be considered written, oral, based on mnemotechnical or multi-medial symbols and separates parts of communication from the context of their conception [25]. Moreover, a notation allows and provokes different ways of reading and interpreting it. It allows a reflective attitude towards the notated and its tradition that can retroact on music in a specific way [25]. As

¹See for example the notational systems by J.M. Hauer, as well as the efforts by Schoenberg, Eimert or others.

²Examples include compositions by Cage, Feldman, Schnebel, Xenakis or Penderecki among others.

³Although *Spac notation* is a term borrowed from the English language, the reader should be advised that its use seems to be confined to musicologists in the German speaking world.

such, notation plays an important part in the creation and development of any musical tradition. Broadly speaking, there are two motivations behind the use of notation: the need for a memory aid and the need to communicate [20]. Traditionally, notation has mostly been written *for* an instrument: a notation that cannot be performed seems unlikely to have had any value before modern music recording was invented.

Here, we want to argue a view on notation as defining it *not* by how it was written, but by the entity that "performs" the score. For this, we want to distinguish it from regular *instructions*. Instead, a notation gives *indications* to the performer as to how the piece should be performed. An instruction is to be executed exactly as written without question, which should be as clear as possible and executable by any machine specifically built to do so. A MIDI with a velocity value note played by a machine in an instruction. A musical notation, on the other hand, is written for a conscious agent with a memory and cultural sensitivity that is capable of interpreting it within its cultural reference using the capabilities of their intelligence.⁴ As stated above, it is to be *performed* and not merely *executed*. To summarize, a musical notation in its broad sense therefore seems necessary for a culture to form, which is written for instruments specifically to be performed in concert.

3.1 Spatial Aspects in Music Notation

Within electronic music, a large category is made up of *fixed media*, or *tape music*, which is music that is foremost played back through loudspeakers without any aspect of performance. Hence, a fixed media composition usually has no need for any score [26]. Nevertheless, fixed media works sometimes have so-called *Aural Scores* written as an analysis or listening aid *after* their creation, most famously for György Ligeti's *Artikulation* [27] or Trevor Wishart's *Vox 5* [26]. Electronic music is seldom performed over a single loudspeaker and some sort of distribution usually has to be done either during production or performance. *Diffusion* is a common electronic music practice, in which a performer diffuses some pre-composed fixed media composition over a number of loudspeakers using a common mixing

⁴At this point, we have to state a finer distinction in that we regard this machine to be built with a limited albeit general purpose in mind and with no AI involved. A machine built specifically for the interpretation of a particular score could be considered an indirect interpretation by the intelligent creator of that algorithm, even if that intelligent creator is an AI itself.

console. An often stated motivation for this practice is the ability to react to the particular listening public and the architectural space in which the work to be performed [10]. If the composers themselves perform, diffusion is often improvised to allow maximum flexibility for each performance space. In the case of *Vox 5* or Ambrose Field's *Still Water* [28] a diffusion score is supplied, which serves as "[...] an approximate guide to diffusion" [26]. For example, Wishart limits his sparse indications to volume values in decibel for speakers in the "front", "rear" or "distance", as he does not want to assume or impose a specific loudspeaker set-up. He writes for the mixing desk, thinking in volume and discrete loudspeakers connected directly to its discrete channels.

Looking at music written for acoustic instruments with or without electronic parts, we find prominent examples of composers particularly interested in the use of space as a compositional mean. In Luigi Nono's work *Prometeo* space also plays a central role by distributing the orchestra and soloists around the audience at different heights. The choreography of sound [29] is achieved using a newly developed spatialisation technology developed by the Experimentalstudio of the SWR in Freiburg scored by means of supplementary notes which were to be read by the technician alongside the score [30]. These notes would outline the performance space, showing the positions for each musician group and loudspeaker, drawing lines how a musician is to be diffused through the loudspeaker system for different sections of the piece. Nono would alter his notes or the number and position of speakers as well as the exact spatialisation in each concert according to the performance space [29, 30].

The distribution of instrumentalists throughout the performance space is not unusual for music within the past century. Iannis Xenakis famously integrated space into his composition based on his experience as an architect and physicist [31]. His work *Terretêktorh* distributes the orchestra among the audience in exact ways to compose mathematical curves along which the sound "moves". The spatialisation in the score is *implicit* in this case: each instrument plays its part like a speaker would its channel, yet holistically the sound appears to be moving in circles and parabolic curves [32]. A similar approach is taken by Henry Brant, who also provides exact floor plans for the musicians through which he is able to define a set of specific trajectories

along which the sound can move and which he would implicitly score through the instrumental notation [33].

As perhaps the most prominent figure in contemporary music in the past century, Karlheinz Stockhausen did not ignore space as a potential for a musical parameter. Similar to the aforementioned approaches, his works *Gruppen* or *Carré* not only distribute musicians around the audience, but several orchestras [34]. In *Carré*, the movements are again implicitly notated through the instrumental score, as *space intervals*, *space accords* or *space glissandi* [35]. Starting from his *Gesang der Jünglinge*, Stockhausen would strive to include the space parameter into his integral serialistic compositions [34]. For his last work before his death, *Cosmic Pulses*, Stockhausen meticulously notated several hundred movements using an 8 channel octagonal loudspeaker set-up, intended for the engineer at the Experimentalstudio of the SWR in Freiburg to spatialise in post-production [36].

In summary, composers often want their spatialisations adapted to the specific performance space, leaving much room for interpretation and improvisation to the spatialising engineer. In order to create some kind of vocabulary, they usually construct some idiosyncratic set of movements as symbols to draw and compose from. The ideas on the use of space though go beyond mere trajectories, as is the case in Nono, for example, where the deliberate goal in *Prometeo* is to confuse the listener from where a source is sounding from. More often than not, placing sounds in different spatial locations has the mere goal to untangle complicated sonic content in order to present a composition in a more digestible manner to the analytic listener.

3.2 Expression Indications in Dance

Western dance notation has been evolving for centuries, from floor designs to geometrical analysis of movement, depending on the particular dance style of each period [37]. For dance theorists, notation is an essential element of composition. It enables to organise the ideas in a choreography and to extend them in an orderly way, and to find common frameworks of structure and expressiveness [12]. It is also important for the development of creativity in young students [24]. As an initial analysis of dance notation, we collect the expression indications from two modern systems: Laban's *Kinetography* (gathered from [24], [38] and [39]) and

the Benesh notation system (from [40] and [12]). Being a symbolic notation system and a representational one, respectively, they do share expression indications. Since we will not review the other aspects of these notation systems, we encourage readers to consult any of the cited books or the multiple on-line resources to deepen in their understanding.

- *Legato*. It is linked to the ideas of continuity and softness of movement. In Bennesh, it has to be explicitly written and it is also used to indicate that all parts of the body are moving at the same time in complex sequences of poses. In Laban, *Legato* is implicitly understood when the direction symbols are not separated by a gap, though the symbol can be used to emphasize the idea of different phrases in a choreography. When there is separation between two direction symbols, the interpretation is *staccato*. It is expressed with the regular the curve used in western music notation.
- *Accelerando/decelerando*. Tempo progressive variations during performance. In Bennesh, it is explicitly written by using the actual words or abbreviations. In Laban, it is normally derived from the dimensions of the direction symbols, but it can also be indicated by the actual words or in numerical form.
- *Amplitude*. Amplitude is associated with the degree of extension of the limbs. In Bennesh, it is implicit when notating the position of the limb in height. In Laban, it has specific symbols, which permit to specify the part of the body involved in the contraction / expansion and the magnitude of the action.
- *Tonicité*. This concept only appears in the Bennesh notation referring to the degree of muscular rigidity when performing a movement.
- *Accents*. In Bennesh, the accents symbols indicate a movement that is performed sharply, with the extra possibility of indicating a sounding outcome.
- *Rebounce*. In Bennesh, indicates a change in the sense of movement caused by repulsion with another body or object. Also, it is used to indicate a slight initial impulse in the contrary sense when starting a certain movement.

- *Energy direction*. In Bennesh, to indicate an external tension source affecting the nature of the movement: pull or push influence.
- *Nuances/Dynamics*. In Bennesh, dynamics symbols from classical western music have been adapted to indicate levels of tension or relaxation during movement. With this, *ppp* means "completely relaxed" and *ff* means "very strong". In Laban, so called *dynamics* are indicated using a complex system of expression marks, the "*effort*" *symbols*. These symbols indicate the *dynamic* quality of the movement as a combination of opposite pairs: "with marked force" - "with lightness", "flow on" - "do not flow on", "quick" - "slow", "direct line" - "indirect line".

4 The Choreographer

The *Choreographer* is a novel software tool intended to build self-curated sets of spatial movements in the periphonic space. Its integration inside the *Binaural Home Studio* (BHS) 3D audio production suite allows users to trigger and combine these movements during performances in real-time and control expression through the available phrasing parameters. Akin to automation curves in most common DAW's, this allows for more flexibility but is also intended to stimulate a new paradigm to think of the complex automation curves as compositional entities by making them savable, shareable and loadable. This applies to single movements as well as the whole set. By populating or loading a list of movements per session, which defines the movement set, the performer or engineer can the freely transition between each movement at any time individually per plug-in loaded. Yet, because of its philosophy, the set of movements is shared among all plug-ins for a session, to draw from the same pool of material.

Although the *Choreographer* is a post-production tool within the BHS, the goal is to develop this tool into a full fledged performance instrument. By removing the focus on the low level coordinate parameters of each source, the tool would be able to facilitate the control of many virtual sound sources similar to how an electric lighting technician is able control a complex lighting set-ups during concert in real-time.

4.1 Parametric Curves

The main editing element in the UI are the parametric curves to manipulate the spatialisation parameters along an undefined time-line. Similar to automation curves, each low level parameter is defined using points to form an interpolated curve where the vertical dimension corresponds to the range of values of the edited parameter, and the horizontal dimension corresponds to time. In order to track the composition of a single movement, the curves are displayed on top of each other, highlighting the currently selected and editable one as "in the front". One important difference to regular automation curves is that circular parameters, such as the azimuth, can be rotated while being projected onto a 2D surface. This makes editing rotations much more intuitive, without having to indicate an instantaneous jump from maximum to minimum, as would be the case for regular automation curves.

4.2 Primary Phrasing Parameters

On top of this, movement phrasing parameters from dance notation in section have been incorporated to enhance expression, specially in live performance scenarios.

- *Legato*: Smooths the parametric curves of a movement, gradually changing the acceleration of the interpolation until all discontinuities in the curve's slope are removed.
- *Staccato*: Widens the resting duration after reaching a point in the parametric curve, effectively creating a abrupt movements.
- *Accentuation*: Changes the interpolation's exponent, to increase the curvature between two points.
- *Amplitude*: Warps the original curve based on a superposition with a triangular curve between two points with the vertex in the middle of the trajectory. The amount of amplitude relates to the vertical distance of the vertex to the original curve.

The parameters are defined in terms of percent and are limited. The exception being amplitude, which could theoretically be described by any positive input. An amplitude of 0 defines the vertex on the original curve, whereas an amplitude of 1 offsets the vertex to

a distance half the difference between the two points. Therefore, any amplitude > 1 would exceed the vertical position of the target point.

The order of the parameters is important, as they are independent but not entirely commutable in the mathematical sense. To smooth the final curve, legato should be applied at the end. Also, in order to prevent staccato from being warped, staccato should be applied shortly before legato. Accentuation and amplitude both describe two curves that are multiplied, meaning their order of computation is irrelevant.

4.3 Loop Mode

The *Choreographer* can have several possible modes of movement:

- One-shot mode: the movement goes through its cycle once only, stopping at the final position, similar to a note on a piano that cannot be sustained forever.
- Loop mode: the movement is looped and stopped by a second trigger. This loop occurs linearly, allowing the amplitude of the movement to be altered during its performance (e.g. using after-touch when mapped to MIDI).
- Ping-Pong mode: similar to loop mode, but the movement traverses the parametric curves forward and backward until the release trigger is sent.
- ADSR mode: the movement has an attack defined, which decays into a sustain section, which is looped. If the release trigger is sent, the release section of the movement is traversed before finishing.

4.4 Temporal Quantisation

A movement is firstly defined a-temporally. The amount of time a movement has to traverse can then be set independently before performance or changed during performance. A reference time per movement is set, from which the performer could then be able to change the duration of a movement relatively. A reference duration for a movement can simply be defined freely in terms of milliseconds or quantized in terms of beats. When in loop mode, the length defines the length of a single loop. If the release trigger arrives,

the movement is either defined to be completed in its defined time before resting in its final position or allowed to abruptly be stopped at the current position. The temporal parameter can also be manipulated during performance of a movement to achieve *accelerandos* and *decelerandos* for phrasing purposes.

Because we are dealing with sound and not human bodies, silence implies invisibility, having a similar effect as an abrupt stop in terms of perception of the movement. This also means that jumps similar to staccato as defined in 4.2 may emerge for the listeners perception, if the source exhibits gaps of silence in its audio content.

4.5 Offset and Mirroring

Similar to how diatonic and twelve tone composition apply inversion and retrograde, a movement may be mirrored in its starting point in both azimuth and elevation. Furthermore, an offset to the movement can be given in all dimensions to apply a transformation akin to "transposition" to a movement into other directions.

This offset could also be defined dynamically by allowing two choreographers controlling each other. Loading a second choreographer and connecting it to the first, a movement loaded in the second one can be used to superimpose a movement on top of another, creating an effective multiplication of the two movements as the result.

4.6 Import/Export Feature

Curves can be exported or imported using open, standardized formats, such as the SpatDIF format [41]. Yet, importing from SpatDIF, for example, might be complicated because the *Choreographer* is not designed to handle a complete scene of many sources as a whole. Importing such a complex description file would require some sort of interface to extract which movement is to be isolated for this import. An easier solution would be to simply refuse any import that exceeds the complexity of a singularly described movement.

4.7 Controller Dichotomy

As a software plug-in, the *Choreographer* doesn't have an innate physical controlling device. In order to truly use it in a performance, something more sophisticated than a computer keyboard and mouse would probably be used. One option is to link its possibilities to

common MIDI devices, like a regular MIDI keyboard. Different MIDI notes could trigger the different movements stored in a set. The "note on" and "note off" messages would control the start and end of a movement. The MIDI velocity could be directly mapped to the velocity of the movement.

Of course, using more sophisticated controllers to track the vertical height of the key pressed or after-touch, for example, would allow for a better grasp on the expressive possibilities built into the tool in real-time. One possibility for future work is to look into how methods employed in complex DMX lighting situations could be adapted to facilitate the control of multiple complex sound source movements. Ultimately, as an instrument a dedicated interface might be designed in the future based on a user centered design approach.

5 Discussion

In section 2, two different approaches to the structuring of choreographies have been reviewed: the first methodology relies on setting a collection of elements related the body attributes and its physical possibilities. A specific combination of these elements (poses, jumps and pirouettes) and the movements of the dancers in the stage space constitute a certain choreography. The second methodology, found in Laban's theories of movement, focuses on the enactment of identifiable paths in space through movement, the dancer being the centre of this space. Laban's comprehensive framework, including the idea of *kinesphere* and the organisation of the space around the dancer, represents a valuable conceptual source that contributes to the discussion about sound-space choreography, especially when working with spherical set-ups. In fact, the sound-movement exploration made by Wishart in [42] starts with a division of the horizontal plane that coincides with that proposed by Laban. Laban's particular approach to space allowed him to indicate movement in a very detailed way using his *Kinetography* notation system. *Kinetography* is therefore a very relevant starting point for possible sound-space notations with a rich approach to sound-movement.

Regarding the search for the *sense of rightness*, we found that the aesthetics of dance are closely linked to the human body. In Blasis, the grounds of beauty are based on body pictorial references and the physical laws of balance; Laban argues that the enactment of the different directions in space and the combination

of synchronous movements convey certain sensations for both the dancer and the spectator. It should be noted that the authors of both theories put a lot of emphasis on didactics to incorporate aesthetic ideas in a practical way. Furthermore, their proposals include the interpretation of a notation as a central element of this learning process [15, 18].

As expression in dance is always related to the body, the knowledge transfer from movement in dance to sound-movement in music should be approached with the following question in mind: does sound-movement expressiveness rely on the illusion of moving masses around the listener? We propose a distinction between *abstract* expressive qualities – movement as absolute musical material – and the case of *dynamic* expressive qualities, i.e. the illusion of a moving mass. The latter is discussed by Wishart in [42], where he mentions the illusion of an *apparent energy* in fast sound-movements, which he identifies as a perceived "intention". We believe that an exhaustive exploration of the expressiveness of sound-movement can help us to discern whether these analogies are inevitable or otherwise if we can find compositional methodologies that are not based on this kind of illusion.

Composition is closely related to notation in both music [25] and dance [12]. As shown in section 3, notation serves as a tool not only to archive and communicate but to reflect and iteratively elaborate on art disciplines. Notations are distinguished from instructions in their ability to be interpreted by a performer using an instrument. It was argued in 3.1 that a notation for spatialisation in music has not clearly developed in the past 100 years. Apart from diffusion practices, spatialisation was usually considered a responsibility for an engineer. The authors therefore have identified the need for an instrument that would allow spatial notations to develop around it.

The *Choreographer* represents a first step in the direction of this hypothetical instrument. The tool aims at a specific and enriching exploration of movement in sound-space compositions. User defined movements are grouped into a set that can be used as a compositional pool of musical material. The three key methodological aspects in the *Choreographer* can be summarised as:

- *Self-curated sets of movements*: As seen in section 2 and 3.1, the idea of quantizing the infinite

possibilities into a set of identified movements has been a recurrent proposal in dance and music approaches.

- *Movements as independent musical material*: Releasing movements from both time constraints and a specific sound object, they can become structuring musical material.
- *Phrasing parameters*: Each movement can be performed with expressive nuances, set before and during the performance of a movement thanks to the implementation of specific phrasing parameters and other higher level manipulations.

As future work, the currently developed expressive parameters in the *Choreographer* should be further abstracted into higher order expressive ones to allow for intuitive control for live performance. In terms of notation, the authors suggest to push for the development of a notation system based on the performance practice, possibly using the proposed instrument, rather than focusing on overly theoretical approaches.

6 Acknowledgement

Thanks to Agustí Ros for his passionate help on reviewing the history of dance and specially for sharing his expertise on Laban's notation with us.

The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 732130 – BINCI project.

References

- [1] Barrett, N., "Ambisonics and acousmatic space: a composer's framework for investigating spatial ontology," in *Proceedings of the 6th Electroacoustic Music Studios Conference*, Shanghai, China, 2010.
- [2] Reynolds, R., "Thoughts on sound movement and meaning," *Perspectives of New Music*, 16(2), pp. 181–190, 1978.
- [3] Jacquemin, G., Coduys, T., and Ranc, M., "Iannix 0.8," *Actes des Journées d'Informatique Musicale (JIM 2012)*, pp. 107–115, 2012.

- [4] Eckel, G., Rumori, M., Pirro, D., and González-Arroyo, R., "A framework for the choreography of sound," in *International Computer Music Conference*, Ljubljana, Slovenia, 2012.
- [5] Ellberger, E. B., Pérez, G. T., Cavaliero, L., Schütt, J., Zoia, G., and Zimmermann, B., "Taxonomy and Notation of Spatialization," in *TENOR 2016: International Conference on Technologies for Music Notation & Representation*, 2016.
- [6] Perez-Lopez, A., "3DJ: A supercollider framework for real-time sound spatialization," in *21st International Conference on Auditory Display*, IEM, Graz, Austria, 2015.
- [7] González-Arroyo, R., "Towards a plastic sound object," in P. Ernst and A. Strohmaier, editors, *Raum: Konzepte in den Künsten, Kultur- und Naturwissenschaften*, Nomos Verlagsgesellschaft mbH & Co. KG, Baden-Baden, Germany, 2013.
- [8] Schmele, T. and Gomez, I., "Exploring 3D audio for brain sonification," in *18th International Conference on Auditory Display*, Georgia Institute of Technology, Atlanta, Georgia, 2012.
- [9] Howard, D. M. and Angus, J., *Acoustics and psychoacoustics*, Focal Press, Oxford, UK, 2017.
- [10] Harrison, J., "Sound, space, sculpture: some thoughts on the 'what', 'how' and 'why' of sound diffusion," *Organised Sound*, 3(2), pp. 117–127, 1998.
- [11] Goodwin, N. and Halfyard, J., "Choreography," Oxford Reference - Oxford University Press, 2011, Online publication (Accessed 12-05-2018).
- [12] Benesh, R. and Benesh, J., *Reading dance: The Birth of Choreology*, Souvenir Press Ltd., London, UK, 1977.
- [13] Forsythe, W., "Choreographic objects," in S. Spier, editor, *William Forsythe and the Practice of Choreography: It Starts From Any Point*, pp. 90–92, Routledge, Abingdon, UK, 2011.
- [14] Blasis, C., *The Code of Terpsichore: The Art of Dancing, Comprising Its Theory and Practice, and a History of Its Rise and Progress, from the Earliest Times...*, Edward Bull, London, UK, 1830.
- [15] Brandstetter, G., "The code of Terpsichore the dance theory of Carlo Blasis: Mechanics as the Matrix of Grace," *Topoi*, 24(1), pp. 67–79, 2005.
- [16] Cunningham, M., "Space, time and dance," *Transformation*, 1(3), pp. 150–151, 1952.
- [17] Cunningham, M. and Lesschaeve, J., "Torse: there are no fixed points in space," in J. Giersdorf and Y. Wong, editors, *The Routledge Dance Studies Reader*, pp. 29–34, Routledge, Abingdon, UK, 1998.
- [18] Laban, R., *Choreutics*, Dance Books Ltd., Hampshire, UK, 2011.
- [19] Brooks, L. M., "Harmony in space: a perspective on the work of Rudolf Laban," *Journal of aesthetic education*, 27(2), pp. 29–41, 1993.
- [20] Bent, I., Hughes, D. W., Provina, B. C., Rastall, R., and Kilmer, A., "Notation," in S. Sadie and J. Tyrrell, editors, *The New Grove Dictionary of Music and Musicians*, volume 18, pp. 73–84, Macmillan Publishers Ltd., London, UK, 2001.
- [21] Jaschinski, A., Jäger, R. M., Grimm, M., and Schumacher, R., "Nichtwestliche Notationsformen," in A. Jaschinski, editor, *Notation*, pp. 227–286, Bärenreiter, Kassel, Germany, 2001.
- [22] Dahlhaus, C., *Notation Neuer Musik*, B. Schott's Söhne, Mainz, Germany, 1965.
- [23] Stephan, R. and Töpel, M., "20. Jahrhundert," in A. Jaschinski, editor, *Notation*, pp. 150–184, Bärenreiter, Kassel, Germany, 2001.
- [24] Challet-Haas, J., *Grammaire de la notation Laban*, volume 1, Institut del Teatre de la Diputació de Barcelona, Barcelona, Spain, 2010, tr. to Catalan by Agustí Ros as 'Gramàtica de la notació Laban; La simbolització del moviment dansat'.
- [25] Möller, H., "Einleitung," in A. Jaschinski, editor, *Notation*, pp. 15–23, Bärenreiter, Kassel, Germany, 2001.
- [26] Williams, T., "Vox 5 by Trevor Wishart. The analysis of an electroacoustic tape piece," *Journal of Electroacoustic Music*, 7, pp. 6–13, 1993.
- [27] Wehinger, R. and Ligeti, G., "Ligeti-Artikulation, aural score," *Schott*, 6378, 1970.

- [28] Austin, L., "Sound diffusion in composition and performance practice II: An interview with Ambrose Field," *Computer Music Journal*, 25(4), pp. 21–30, 2001.
- [29] "Luigi Nono Prometeo Tragedia dell'ascolto," Concert Programme, Rolf Böhme Saal, Freiburg, 2003.
- [30] Jeschke, L., *Prometeo*, 42, Franz Steiner Verlag, Stuttgart, Germany, 1997.
- [31] Harley, M. A., "Spatial sound movement in the instrumental music of Iannis Xenakis," *Journal of new music research*, 23(3), pp. 291–314, 1994.
- [32] Santana, H., "Terretêktorh: space and timbre, timbre and space," *Journal of Compositional and Theoretical Research*, 9(1), 1998.
- [33] Harley, M. A., "An American in Space: Henry Brant's "Spatial Music"," *American Music*, 15(1), pp. 70–92, 1997.
- [34] Stockhausen, K., *Texte zu eigenen Werken, zur Kunst anderer, Aktuelles, Band 2*, volume 2, M DuMont, Cologne, Germany, 1964.
- [35] Frisius, R., *Stockhausen Die Werke 1950–1977*, Schott, Mainz, Germany, 2008.
- [36] Frisius, R., *Stockhausen Die Werkzyklen 1977–2007*, Schott, Mainz, Germany, 2013.
- [37] Guest, A. H., "Dance notation," *Perspecta*, 26, pp. 203–214, 1990.
- [38] Preston-Dunlop, V. M., *Practical Kinetography Laban*, MacDonald and Evans Ltd., Norwich, Norfolk, 1969.
- [39] Guest, A. H., *Labanotation: the system of analyzing and recording movement*, Routledge, Abingdon, UK, 2014.
- [40] Mirzabekiantz, E., *Grammaire de la notation Benesh*, Centre National de la Danse, Pantin, France, 2015.
- [41] Peters, N., Ferguson, S., and McAdams, S., "Towards a spatial sound description interchange format (SpatDIF)," *Canadian Acoustics*, 35(3), pp. 64–65, 2007.
- [42] Wishart, T. and Emmerson, S., *On sonic art, Chapter 10*, volume 12, Psychology Press, 1996.