Exploring the Three Dimensional Spatiality of Polyrhythmic Drum Improvisation

Jeremy Ham¹, Joachim B. Kieferle², Uwe Woessner³
¹RMIT University; SIAL Sound Studios ²Hochschule Rheinmain ³University of Stuttgart High Performance Computing Centre
¹jeremy@surfcoastarchitecture.com.au ²joachim.kieferle@hs-rm.de ³woessner@hlrs.de

This paper reports on creative practice design research founded on the translation of complex polyrhythmic digital drumming into the spatial domain. We outline four exercises in the use of drumming improvisation as a methodology for the spatialization of polyrhythmic drum improvisation; as static Spatial Drum Notation and representation as 3D models, artefacts and in Virtual Environments and live drumming performance inside a VR CAVE. These creative exercises bring forward concepts of affordance of musico-spatial representations, a theoretical ‘musico-perspectival hinge’ and the continuum of performance, notation and representation.

Keywords: Music and Architecture, Drumming and Polyrhythm, Virtual Reality

INTRODUCTION

This paper reports on design research operating at the intersection of music and architecture within the context of a post-Xenakian musico-spatial design creative practice. The great Iannis Xenakis provides the template for a creative practitioner operating within and across the domains of music, architecture and beyond. Through the linkage between scored compositional works such as Metastasis, and architectural works such as the design of the Philips Pavilion (ostensibly under Corbusier’s name) wherein ruled surfaces are derived from glissandi from his composition, Xenakis shows us how the designer can operate within and across domains. His propensity for complexity is manifested through his expertise in mathematics, computational and stochastic music and his unique notation systems and methods as outlined in his manifesto, Formalised Music (Xenakis 1971).

Since Xenakis, there have been many design investigations into what Elizabeth Martin describes as the “Y-Condition”: ‘the middle position of music and architecture when translating one to another (Martin 1994)’. The work of, for example, Ferschin, Lehner et al. (2001), Radojevic and Turner (2002), Christensen and Schnabel (2008) Krawczyk (2012) and Fowler (2012), utilize computational methods to translate elements of music into the spatial domain. The comparison with the quote attributed to Johann Wolfgang Von Goethe, that ‘music is liquid architecture; architecture is frozen music (von Goethe 1832)’ has been used by many as the basis for comparisons be-
between the domains. This literal association, however, acts to simplify a complex set of associations wherein the designer has access to multiple means and methods through which to map, translate and parametrise musical elements in the spatial domain.

In relation to the connection between music and spatial design (architecture), three elements differentiate our research from much of the previous works on music and architecture:

- The focus on drumming performance on the digital drum kit as the driver for the creative practice.
- The focus on improvisation on the digital drum kit as a generative modality.
- The focus on the translation of music in the spatial domain as notation and as representation.

The creative practice research is undertaken through the teamwork of a drummer-architect in association with computational architect and Virtual Reality visualisation specialist. The principal proposition is that significant opportunities are available in the use of computation tools, media and methods to form a bridge through which to examine elements of the creative process of music making. We utilise computational tools to provide spatial definition to drum-based improvisation in both an analytical and generative capacity.

Through translation of digital drum music into the spatial domain, we propose that novel insights are afforded into the complexities of polyrhythmic drumming that are not available through translations into traditional musical notation. We speculate on the affordances of operation across representational media in 2D, 3D and Virtual Reality in both static and live playing. The concept of ‘affordance’ was established by Gibson (1979) was furthered by Norman (2002) to relate to design, wherein the attributes of designed objects provides visual cues as to how they are to be used. Thus, our paper provides a snapshot of four scenarios wherein polyrhythmic drumming is translated into the spatial domain and we offer insights into the affordance each medium provides in terms of performance, notation and representation.

**DRUMMING, POLYRHYTHM AND IMPROVISATION**

To begin to understand the higher order complexities of polyrhythmic drumming, we must first outline what it is that drummers do. The art of drumming involves the physical interaction with the drum kit with hands (via sticks) and feet to produce drum beats, fills (short expressions within or alongside beats) and drum solos. For the purposes of this study, we concentrate on drum playing within a solo capacity. Drum beats, fills and solos operate as the placement of overlays of notes (bass drum, snare drum, hi-hats, tom toms and cymbals) within a meter or tempo (measured in beats per minute) along a time line. Capacity to play in time, with other musicians and creatively is a function of training, practice and individual creativity. Bruford (2015) defines the ‘Functional-Composition Continuum (FCC),’ as the creative spectrum of drummers: from ‘recreative’ drummers who just ‘make it work’ to highly expressive, technical and creative drummers that ‘challenge the limits of the known drumming world (Bruford 2015).’

We argue that live drumming is a highly complex creative activity that occurs in real time, with microsecond response and reaction times that acts as a very intense, quick and responsive design activity. Live drumming requires the instantaneous engagement in ‘tacit-knowing-in-action (Schön 1983)’ using a lexicon of ‘referent (Pressing 1987)’ patterns and phrases built up over the performers career. The speed at which musical decisions are made highlight...
the drummer’s capacity to ‘design’ in real time and in response to internal ideation in a solo capacity or interactions with other musicians.

We are interested in the more complex, compositional end of the FCC, and focus on polyrhythmic drum improvisation. Polyrhythmic drumming ‘require(s) the simultaneous production of two (or more) conflicting but isochronous motor sequences (Summers and Kennedy 1992).’ For drummers, this occurs when the drummer overlays several time signature elements within a beat or solo contemporaneously. A basic polyrhythm may consist of the right hand may be laying 5 beats whilst the left hand plays 3 beats during the same time period. Virtuoso drummers such as Bill Bruford and Terry Bozzio perform highly complex, multi-limb polyrhythms in the form of ostinato patterns in solo performance. This highly complex, polyrhythmic drumming is the foundation for the exploration of diversity in musical creativity and is the focus of our exercises outlined below (see Figure 1).

Improvisation is a highly evolved skill that operates at the end of the FCC to enable the instantaneous generation of musical ideas. Whilst much research has been undertaken on the neurophysiology, methods and models of improvisation Pressing (1987), phenomenology Benson (2003), the Field of Musical Improvisation Cobussen, Frisk et al. (2010), improvisation theory and the relationship between jazz musical improvisation and architecture (Brown 2006), we propose improvisation as a methodology. We also propose that improvisation is a design activity. Through modalities of playing and repetition on the digital drum kit, a massive amount of musical data can be generated that provides insights into the form, shape, patterns and phrases of a players’ repertoire. Through improvisation, the id, the personality and the style of the drummer is revealed. The fluidity and flow of the musician’s engagement in the instrument is a phenomenon that provides the basis for entertainment, analysis and, in our case, as a means of exploring connections between the domains of music and architecture. The key to the extemporization of music is the enabling of this flow in ways that may not be fully fluid in parametric tools and processes (Ham, Schnabel et. al. 2016).

The key to polyrhythmic improvised drumming is the purposeful generation of complexity through bodily engagement in the instrument. Through training, practice, repetition and copying and evolving the drumming of others, highly complex combinations of patterns and phrases are enabled wherein polyrhythm occurs at the macro and micro scales. A macro-scale polyrhythm may form the temporal foundation of a musical piece or drum solo. Within this overall time structure, a highly skilled drummer will be able to introduce small-scale repetitions of this structure, or even different polyrhythms founded on different time signatures, tempi or other complex combinations. Like architectural designers, not all drummers purposefully seek complexity. The style of the drummer, as with the architect, is a highly complex combination of factors. Ultimately, the success of a polyrhythmic drumming performance is measured in terms of musical aesthetics—whether through responsive perceptions of order and harmony (e.g. Miles Davis) or disruption (e.g. The Sex Pistols or Slayer).

This aesthetic is manifested also in the notational aesthetic, in the way in which polyrhythmic patterns and phrases are transcribed into traditional notation (See Figure 1). We are interested in the exploration of ways of representing polyrhythmic digital drumming and outline four exercises through which we have explored this translation of music into the spatial domain as a means of enhancing the affordance of the musical notation, providing virtual immersion and as a generative means of creating music and spatial elements in the CAVE.

FOUR EXERCISES IN POLYRHYTHMIC DRUM IMPROVISATION SPATIALIZATION

1. Exercise 1: 3D Spatial Notation and Representation of Polyrhythm

The foundation of the first three exercises was a massive musical data set derived from a hundreds of improvisations on the digital drum kit, as described in
Ham and Prohasky (2016) and Ham et. al. (2016). Improvisations on the digital drum kit are played live in the studio, recorded as sound, captured in MIDI (Musical Instrument Digital Interface) format, exported from the Reaper Digital Audio Workstation in MIDI format then translated into .csv format. From here, a Rhino 3D Grasshopper definition assigns spatial parameters to the MIDI attributes of drum events in time, note velocity and note duration. Drum events from each ‘note’ on the digital drum kit are represented as a timeline along the “Z” axis; with velocity (the intensity of the hit) with note duration manipulated using the full range of tools available in Grasshopper. From this, a 3D spatial drum notation system was developed that represents the spatiality of the drum kit and acts as an alternative to traditional music notation (see Figure 2).

Through playful manipulation of the musical parameters, multiple creative outputs have been explored that enables the spatialization of drum data as architectural elements (tunnel structures, panels, lattices etc.). Through the strategic placement of drum notes as lines along a Y axis, polyrhythmic drum patterns can be represented as clusters along the X axis with note velocities represented along the Z axis. From this, a series of spline curves are sent along each drum note, and then the resulting curves are lofted in Grasshopper. Through this process of lofting, the core drum data is stylized and abstracted, allowing for creative interpretation of the form and flow of a polyrhythmic drum improvisation to occur. This technique has been used to provide a spatial representation a six part improvised drum composition, ‘Layered Relationships’ (see Figure 3). By overlaying the spatialized layers of the composition, the lofting highlights the complexity of drumming patterns and the inter-relationships between constituent elements of a musical composition wherein this highly complex representation becomes an art form in itself. This methodology enables representations provides pathways into digital fabrication and 3D printing, which are outside the scope of this paper.

2. Exercise 2: Static 3D Spatial Notation in Virtual Reality

Working with the University of Stuttgart High Performance Computing Centre Virtual Reality 5-sided CAVE (Cave Automatic Virtual Environment), we have experimented with ways of extending 3D Spatial Drum Notation within Virtual Environments (VE). By importing VRML files of drum improvisations into the CAVE, spatial immersion into the Virtual 3D ‘score’ is enabled (See Figure 4). These scores represent drum notes along different elements of a timeline, defined by bars in a spiral notational schema that represents the spatiality of the digital drum kit (see Ham, 2016). One of the principal attributes of the 3D Spatial Notation is the ability to freeze (bake) polyrhythmic drum improvisations thus locking in the relationships between elements of the polyrhythm. This may include including ghost notes, slurs and low-velocity accents that constitute the elements of individual style. Velocity (how hard a drummer strikes the drum) is an
essential ‘lever of control (Bruford 2015) for the hierarchisation of complex polyrhythmic overlays and patterns, wherein a minor polyrhythmic patterns can operate below, in and around the foundational drum pattern being played. By ‘flying through’, in and around drum improvisation spatializations in Virtual Reality, detailed examination of these musical ‘design decisions’ that constitute a drum improvisation is enabled.

The problem with this mode of operation is the dissociation between the musical output and the spatial (notational) representation of the drum polyrhythm. This dissociation is the same as any symbolic notation system, wherein the language of notation needs to be learnt in order to translate, enact or analyse the score. 3D musical notation in Virtual Reality is noted by Hmeljak (2000) to be ‘the most intuitive representation of music’, and should include ‘an appropriate use of symbology and geometry...(and) the use of colours and colour mapping.’ We address this and further enhance affordance by colouring different drum notes and using sphere radius to represent velocity.

3. Exercise 3: Dynamic 3D Spatial Notation in Virtual Reality

The second method of spatialising drum improvisations in the CAVE involved the development of a plugin to read MIDI files directly into the VR software. This enables the playing of the sound of the drum polyrhythm contemporaneously with the visualisation in Virtual Reality in the CAVE. The 3D Spatial Notation schema was adapted and translated into a VRML spatial container. Drum notes are represented as colour coded spheres emanating from the spiral container, with sphere diameter and the initial velocity with which these spheres are emitted in virtual space dependent on the note velocity. The spheres are integrated along a force field providing a gravity-like effect, thus enabling a second layer of experience in, and around the person in the CAVE.

This real-time dynamic spatial notation, alongside the sonic output provides affordance to understanding drum-based polyrhythm in both the sonic and spatial domains. The temporal relativity between the spatial immersion in the ‘design’ decisions of the drummer making the polyrhythm and the sound output within the CAVE allows for a very quick learning curve on understanding the meaning of the 3D notational schema. The dual modes of visualization of note velocity (sphere diameter and initial velocity vector) provides further affordance to the understanding the dynamics that constitute personal drumming style. The element of time and space is introduced by the velocity-dependent projection of drum events into the CAVE. VR users can move forward in space to experience drum events that have recently occurred contemporaneous to hearing and seeing current musical events (See Figure 5). This spatio-temporal engagement is thus a defining element of dynamic representation and notation in CAVE environments.

4. Exercise 4: Live Drumming in Virtual Reality

The fourth exercise reported here involves the installation of a digital drum kit inside the CAVE, with
the simultaneous output of MIDI data to the visualisation engine and sound to speakers inside the CAVE. This overcomes the time and effort overhead in recording drum improvisations and translating these recordings into MIDI and / or spatial form. The spatial template adopted for this exercise was founded on the drummer as the key actor in the CAVE, and utilised the same notational language of spheres from previous exercises. Spatial forms generated from live drumming emanate radially in and around the drummer, as the central actor in the CAVE. Whereas Exercise 3 projected note velocities “up”, this exercise projected notes “out” and away from the drummer. In order to achieve this, the force field which accelerates the particles was changed to a radial field. Initial velocities not only change their magnitude depending on the velocity of the note but also change their orientation. High velocities are oriented forward and low velocities backwards, towards the drummer.

Through live play directly inside the CAVE environment, with 3D glasses on, the drummer generates the sound and constructs the virtual spatial elements contemporaneously. The act of playing inside the CAVE—generating sonic and spatial outputs whilst responding through improvisation to these visualisations redefines the definition and potential modalities of both drumming and improvisation. The drummer becomes a spatial drummer, improvising variably using a pre-defined (but always evolving) language of ‘referent (Pressing 1987)’ patterns and phrases but completely new spatio-temporal patterns and phrases in the virtual environment. The necessity to wear 3D glasses further acts to disengage the drummer from the drum kit, and improvised response is to spatial emanations appearing before the drummer’s eyes (See Figure 6). A feedback loop of the gravity engine returning previously played note representations to the field of vision furthers improvisational opportunities as the drummer can improvise in response to the dynamic events occurring in and around him or her.

AFFORDANCES IN EXPLORING THE SPATIALITY OF POLYRHYTHMIC DRUMMING

Each of the modalities described above has distinct attributes that provide affordance to the understandings of music through notation, representation or immersion and experience, operating within a continuum of live performance to notation to representation. Following Rebelo’s (2010) purposes of musical notation as being to document, to communicate, to reflect and to produce, design representations aim to ‘achieve (a) situational awareness that allows for meaningful criticism of design (Kalisperis and Pehlivanidou-Liakata 1998)’. These notations and representations are either static. A static representation appear to have the advantage of better enabling reflective and analytical modalities, thus providing affordances unavailable in dynamic representations.

Exercises 1, 2 and 3 utilise pre-recorded MIDI files derived from historic drum performances, thus the experience and analysis can occur long after the performance has been completed. We describe in this paper only a small element of a larger creative practice embodied in Exercise 1. The outputs available for the analytical, representational and creative translation of drum polyrhythm are many, however the process of translation (from drum performance, to MIDI to CSV to CAD) is time consuming. This is where the scripting for the CAVE, by virtue of reading directly from the MIDI data, significantly reduces overhead and the errors and glitches that sometimes occur in translation.
The third and fourth exercises introduce the element of dynamism and movement to the spatialization of polyrhythmic drum improvisation. Although static representations appear to be more useful for notational purposes, dynamic CAVE spatialization of drum polyrhythm operate better at the representation and performance ends of the performance - notation-representation continuum. We report on two short workshops held in the CAVE, thus the extent of design creativity into CAVE-based spatialization is limited. However, the principal experiential attribute of working in VR in the CAVE is dynamism- and dynamic representations of drum music in the CAVE provide a different affordance to static representations.

The generation of sound contemporaneous to dynamic spatial representations in the CAVE enhances the sensory affordance by enabling the simultaneous engagement in the polyrhythmic drumming with both eye and ear. Static representations may require additional cognition in order to afford understandings because of the intrinsic dissociation between the musical and sonic representation and the spatial representation. Adopting the concept of the ‘perspectival hinge (Pérez-Gómez and Pelletier 1997), this ‘Musico-perspectival hinge’ acts to limit understandings of music in ways that are similar to the limitations of 2D drawings to understand design (Ham 2017). We propose that the direct association between dynamic spatial representations in Virtual Reality and musical (sound) output from MIDI files enhances the affordance by further breaking down this musico-perspectival hinge.

Drumming in Virtual Reality brings together the contemporaneous generation of musical output and spatial representations through the act of live performance in the CAVE. Principal to the playful engagement in the spatialization of music is the ability to purposefully play the musical instrument with the intention of generating music, music and spatial output or spatial output alone. Whilst the form of spatial output in these early investigations is very basic, learning the parameters, and playing the parameters is fundamental to successful engagement. Knowing the system, and gaming the system, is key. Drummers, as experts in real time music ‘design’ decision making, with skills, dexterity and experience with the interface of the drum kit, hold an advantage in their ability to generate both musical and spatial output in the CAVE.

Live drumming in the CAVE allows performance to serve as the driver for the creative and dynamic generation of complex polyrhythmic drum music. Significant opportunities in performance art arise from this modality. The experiential opportunities for the drummer in the CAVE purposefully generating virtual spatial forms and music for an audience in the CAVE are considerable. For the drummer, creative opportunities arise from the knowing generation of spatial forms ‘in front of their eyes’ but also the creative musical reactive feedback loop between the dynamic forms previously generated and improvised response. This environment truly redefines the “Y-Condition” - the theoretical middle position between music and spatial design where the architect-drummer acts as spatial designer and musician contemporaneously. This ‘musico-spatial design’ modality offers new opportunities in the domains of both music and spatial design that are currently being explored.

CONCLUSIONS AND FURTHER RESEARCH
We have outlined four exercises in the exploration of the “Y-Condition” as the intersection of music and spatial design (architecture) that operate along the continuum of musical performance to the notation and representation of music in the spatial domain. Each of these methods, representational outputs and environments provides different and contrasting affordances to the understanding and experience of the structural and relational elements of complex polyrhythmic drumming. Whereas static representations may provide greater affordance for analytical purposes of 3D Spatial Notation, dynamic representations, when visualized in Virtual Reality, offer greater creative insights into the dynamic aspects of drumming music. Returning to the post-Xenakian concept of an integrated ‘Musico-Spatial Design’ cre-
ative practice, we propose that the exploration of the spatiality of polyrhythmic drum music in the form of live drumming in the CAVE allows the drummer the greatest level of design exploration. This is particularly relevant for persons skilled in both music and spatial design. We are working beyond the basic spatial representations presented in this paper towards ways that fully relate to the complexities of polyrhythmic drumming. We propose that an extension of drum-based performance in Virtual or Augmented Reality into full multi-speaker spatial sound holds great potential for both enhancing the affordance of the connections between music and spatial representation and creative potential of the musico-spatial design creative practitioner.

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