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SHARING DIGITAL PERFORMANCE NOTATION WITH THE AUDIENCE

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Abstract: **In performance, music notation usually functions as an abstracted intermediate step between the activities of musical composition and realisation. We present an extended interpretation of digital notations situated with respect to the disciplines of music composition and performance, interaction design and the Cognitive Dimensions of Notations framework. Our case study is a pitch-space visualisation project employing 2D and 3D representations, including a spiral helix and pitch-class clock, that are integrated in real-time with SuperCollider synthesis to indicate harmonic and/or melodic progression. Rather than simply a tool for music analysis and pedagogy, we argue that this software functions in a context where different and complementary experiences can be provided to performer(s) and audience.**

Keywords: interaction design, notation, performance, SuperCollider

1. INTRODUCTION: SHARING NOTATIONS

In music performance involving score notation, the score is traditionally unseen by the audience. *Digital* performance technology, however, enables the sharing of notation with an audience. Audiences may appreciate this alternative to the historical presentation of acousmatic music, in which the loudspeakers are the only visible 'performers'. In live coding of computer music, too, a tradition of sharing a view of the computer code has now existed for at least a decade [1].

It can be argued that sharing computer code with an audience in live coding practice shifts the emphasis from software, to the programmer as performer on stage, bringing the experience for an audience closer to that of traditional music performance. Such a move towards *sharing* is in sympathy with a post-war desire towards transparency of communication in art [2]. Although sharing code with an audience can help shift emphasis to the act of programming, as a notation, code itself is usually a highly abstracted representation of heard music, likely foreign to all but fellow programmers. A key aim of the work presented here is to overcome this barrier.

As a symbolic representation of sounding music, common Western music notation (CWN) is a highly evolved and efficient method of indicating musical intention within the Western music tradition [3]. As a highly specialist notation in itself, however, it also suffers from many of the barriers as computer code for sharing musical intent with an audience. This has been one motivation for artist-programmers to create graphic music notations offering alternative representations of musical processes. In this respect Hall's software, PitchCircle3D, introduced below, shares an apparent aim of Magnusson's 'Threnoscope' [4], to broaden the accessibility of and maximise communication of musical processes to non-specialist audiences. Of course, different approaches to graphic music notation offer design trade-offs in terms of representation of musical parameters, as discussed further below. We next introduce the software used in this project, before contextualising its use in a collaborative performance project in relation to the Cognitive Dimensions of Notations framework.

2. PITCHCIRCLE3D

PitchCircle3D is series of custom classes written in the SuperCollider programming language [5], a sophisticated computer music environment for real-time computer music synthesis. The motivation for PitchCircle3D is to enable sharing a form of music notation with performers and audience alike. The implementation as a system within a system within SuperCollider [6] allows, to use Leman's term, 'micro-integration' [7, p.3] with the software's audio synthesis engine for use in responsive electronic music performance.

PitchCircle3D uses SuperCollider's cross-platform GUI environment (implemented in Qt) to display live music notation in the form of notes and chords in 12-tone equal temperament (12-TET), as shown in Fig. 1 . The notation view is animated at a customisable fps rate and can be updated in real-time via SuperCollider's interactive programming environment. Since PitchCircle3D is implemented in SuperCollider, it can also be easily configured as required to respond to external control through e.g. MIDI or OSC messages, discussed further below.

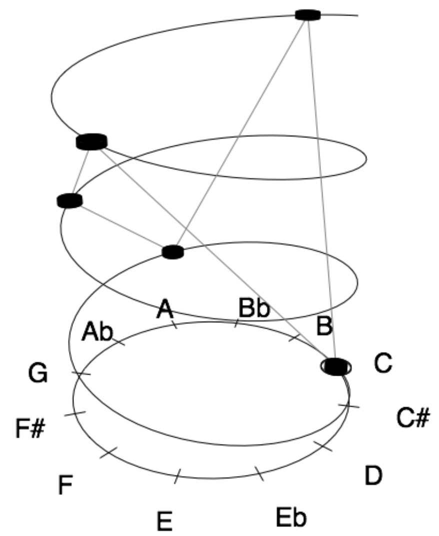

Figure 1: PitchCircle3D spiral notation view.

Animation of PitchCircle3D's views includes methods to smoothly tilt, rotate and zoom views, programmatically or by mouse interaction. PitchCircle3D currently has three notational views. A 'pitch clock' shows pitch-classes (omitting registral information). A 3D spiral helix illustrates relative register, shown over three octaves in Fig. 1. In each view, small discs represent potentially sounding pitches, by default connected by a line passing through each. Ordinarily the notation indicates corresponding pitch-classes with a customisable colour for each pitch/pitch-class. An additional small circle around a disc is available (shown in Fig. 1 on the lowest note C) to indicate a point of emphasis, tonic or area of pitch centricity.

Notes can be entered and removed individually or in groups, faded in and out at a desired rate and displayed for a specified duration, starting either immediately or at some future point in time. These operations create a series of 'time points' to structure musical progression according to pre-defined or algorithmic sequences. As an example of the simplest operations, the following SuperCollider code generates the view shown in Fig. 1:

```
p = PitchCircle3D.new(numOcts:3);
p.front;
p.ezAdd([60, 95, 69, 79, 89], 60);
```

```
p.rotateTo(9.5);
p.tiltTo(5.9);
p.clearAll; // remove discs
p.close; // close window
```

The notational representations available in PitchCircle3D are in themselves not novel, although their particular implementation and the software's performative context offers affordances otherwise not available. Related software include iPhone apps *Music Set Theory* [8] (clock view) and [9] (animated 3D spiral view). Like PitchCircle3D, Chew and François' software MuSA.RT also displays pitches around a spiral helix, and can do so using live MIDI input [9]. Its scope, however appears to be narrower than that of PitchCircle3D, as it is intended to illustrate a specific theory of the analysis of tonal music. MuSA.RT is primarily a tool for music analysis, whereas PitchCircle3D in intended for broader use, including as a digital musical score.

3. Computer Music Scores for Improvisation

3.1. Collaboration through shared notation

The long tradition of computer music scores includes some intended for realisation in computer music, others as notation of pre-existing music. However there has also been a sense that the medium produced mixed results in its early decades [10]. Digital scores, however, since they cab be updated in real-time, offer more scope for notational interactions. Whilst PitchCircle3D can be used as a simple visualisation of note music, its implementation is intended to aid computer-assisted performance, acting as the shared notational space between performer-collaborators.

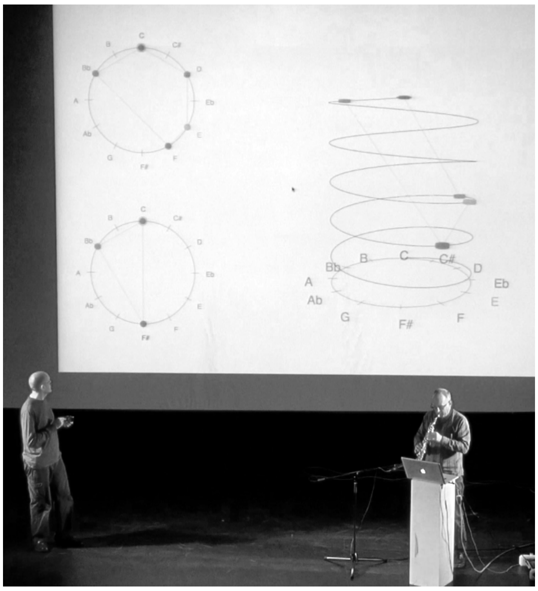

Figure 2: *All the Chords* on-stage configuration of performers, computers and notation.

In 2014 PitchCircle3D was used in a configuration for performance of Hall's composition *All the Chords*, involving an instrumental musician, Kevin Flanagan (saxophone), and computer performer (the composer). In performance, PitchCircle3D was used in full-screen mode, and a mirrored screen projected on the rear of the stage. The instrumental performer mediated aspects of the performance, viewing the notation on the screen of the laptop running SuperCollider, whilst the computer performer referred to the notation on the rear projection, as shown in Fig. 2. SuperCollider was used to both display the notation using PitchCircle3D, as well as to synthesise a computer music part. Communication with the main computer laptop was via the Open Sound Control (OSC) protocol. Rather than achieving this via a second laptop, all communication with SuperCollider was via a mobile device in order to have the most direct on-stage communication with both the instrumental performer *and* appear most present to the audience.

To communicate with the laptop via OSC, the mobile device ran a customised layout of the TouchOSC app [11]. Fig. 3 shows the TouchOSC controller view available to the computer performer. OSC messages were sent in both directions, with the computer updating both the elapsed time and current chord number of the composition to the mobile device. By default, the main XY-plot area is a manual trigger that advances the next performed / displayed predetermined chord, with the X axis altering the timbre of the chord, and the Y axis determining the chord's amplitude. The 'Auto play toggle' button overrides the manual advancement of chords, instead using a predetermined algorithmic sequence of time interval between chords within SuperCollider. The right side of Fig. 3 shows one of two available panels allowing amplitude mixing of stratified compositional layers within the piece: chords, drones, arpeggiations, bass notes and overall mix volume.

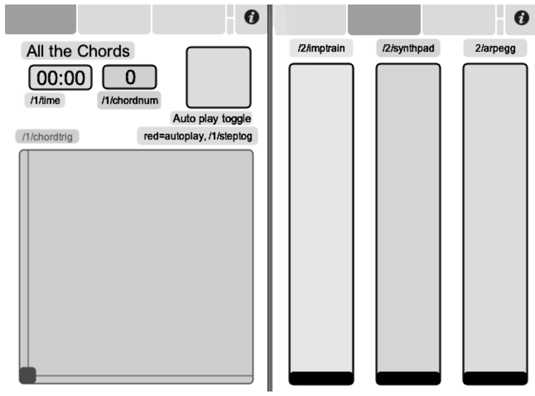

Figure 3: Interactions available with mobile control via OSC.

3.2. Indeterminacy

As a representation of musical events, PitchCircle3D's notations combine aspects of events both indeterminate and fully determined. The software's default spiral helix view is fully determinate in terms of its notation of pitch-space, whilst its clock view, as shown Fig. 4, presents pitch-class space only, necessarily omitting registral information (this figure in fact represents the same pitches as those in Fig. 1). Whilst it might be expected that the choice between displayed views would depend on the level of pitch determinism required, experience in performance has found a friction in reading the spiral helix view quickly and without error. Thus even where pitch is fully determined, in practice the spiral helix view has usually been presented simultaneously with the corresponding clock view. This configuration can be seen on the top left hand side of Fig. 2.

The rhythm and tempo of musical events are not represented in PitchCircle3D other than in the timing of display transitions ('time points'). Thus the project sits between other recent approaches in digital notation that are more indeterminate (graphic notation), or fully determinate—for example employing CWN (such as [12]). Design decisions behind PitchCircle3D offer clear constraints for performance (what notes to play), but leave others relatively open (when and how to play), a mode of performance well documented since at least the 1960s [13] and further contextualised within the context of the Cognitive Dimensions of Notations framework below. This notational indeterminacy of PitchCircle3D can be regarded as an affordance, leaving as it does considerable room for collaborative musical improvisation. Indeed, the design of PitchCircle3D sits well with established models of musical improvisation [14], something beyond the scope, however, of this paper.

In the 2014 performance using the software, temporal constraints of the musical improvisation were partially determined by the duration over which each note/chord was displayed. As discussed above, the duration was in turn determined either algorithmically, or through mediation by the computer musician. Likewise, timings of musically notated material and the relationships between this material thus influenced the resulting types of musical continuations. Musical decisions and outcomes were thus the result of the collaborative nature of the musical improvisation, which functioned according to a specific set of interactions next outlined.

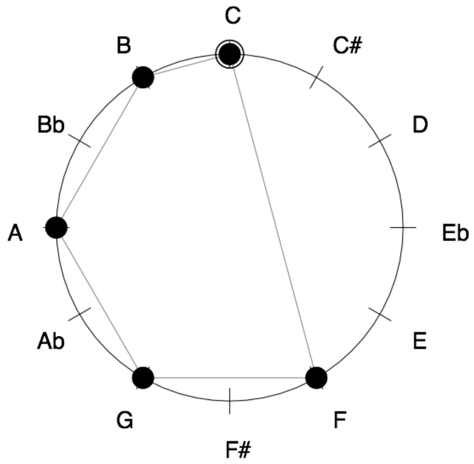

Figure 4: PitchCircle3D clock notation view.

4. Interactions

4.1. Cognitive Dimensions of Notations Framework

The Cognitive Dimensions of Notations framework [15] provides a critical vocabulary for discussing the ways in which notational systems are likely to support or inhibit cognitively demanding tasks. The framework draws on fields such as cognitive task design and external cognition, but emphasising the implications for design of novel notations. A key insight of the framework is that one's experience of any notational system is a corollary of the activity one is engaged in. For example, a creator/writer might be impeded by the dimension of 'viscosity' if a notational system does not easily accommodate changes of intent. Meanwhile, readers are unconcerned by viscosity because they do not manipulate or modify the notation. Where notations are seen both by performers and audiences, semiotic analysis must consider the alternative patterns of user experience by which each engages with and interprets compositional structures and intent in the performance context.

In the specific case of PitchCircle3D, the notation is explicitly intended as a shared communicative representation, which might be compared to the use of shared representations in collaborative work contexts [16]. Recent developments drawing on these different theoretical accounts of representation use have described the recurrent patterns of experience that people have with information systems, encompassing both individual cognitive tasks and these broader communicative situations [17]. Recurrent patterns of experience become a design resource, just as architect Christopher Alexander describes patterns of experience that people have within the built environment [18].

The narrative demands of a notation include ensuring that the overall story is clear, providing a gestalt view of the whole information structure—viewers can 'stand back' and look at the overall configuration, and get a good idea of the whole story. This involves making the elements visible, but also eliding or summarising to achieve a concise visual layout. This might be achieved by showing fewer relationships although the result is often abstract, with less chance that users will find it familiar. Collaboration requires shared reference, which in the case of PitchCircle3D entails a correspondence between the notes played and the overall scheme that is apparent to players (as collaborators) and audience (as readers). There is a tension between fluidity of information transfer (for example, where rising pitch corresponds to height on the screen), and the satisfaction that comes from having to stop and think (identifying familiar harmonic structures within the unfamiliar polygons of the pitch circle). The indeterminacy of this last requirement offers the opportunity for all readers to see something different when they look again—as a new possibility for exploratory improvisation, or an alternative interpretation of what the audience has heard.

All readers of PitchCircle3D are engaged in sense-making. Clarity remains important, but so is the control of visual attention—colour and moving components draw the attention of the audience to those parts of the notation that they are expected to relate to what they hear. When they view this relatively complex diagram, they also draw relations between the parts—the (implicit) vertical correspondence of the pitch class labels to the upper spirals, and the (explicit) visual continuity of the lines linking chord elements. However, these visual conventions will be unfamiliar for many readers—they are neither iconic nor indexical. However, the addition of pitch labels (B-flat, C-sharp) offers a consistent reading of those parts of the representation having a correspondence to basic elements of music theory, even to audience members with minimal musical training. Sense-making is an active process, in which inviting the viewer to think about what they see is an essential component. At present, PitchCircle3D is not available to players and audience members as an interactive experience, but one might consider ways in which it could draw them in, encouraging viewers to 'play around' with alternative configurations or renderings.

4.2. Feedback of Interactions

Next we analyse the collaborative performance using PitchCircle3D discussed above in terms of a feedback of interactions. Fig. 5 illustrates this feedback of interactions between the two performers, digital notation, and the sounding musical performance (influenced by Nash and Blackwell's approach to diagramming user interaction within music software [19]). Note that the majority of these interactions function as iterative feedback loops which may operate on multiple timescales.

The Cognitive Dimensions that are essential to such feedback are related to Provisionality (is it possible to create elements of the notation that may not be the final product) Progressive Evaluation (to what extent is the system able to modify its operation in response to the current state of the notation) and Premature Commitment (does the workflow of system operation require certain decisions to be made at a point other than where they naturally fall in the creative process).

In the case of PitchCircle3D, the instrumental performer did not manipulate the digital notation (and sounding electronic part), except indirectly through visual cues to the computer performer. It is also helpful to understand that the notation and music are in a sense at any moment types of abstract representations of the other, whose relationship is determined by the type of improvisation occurring. Thus paths through these iterations occur in a layered fashion, in which the notation is realised through improvisation by the performers. The attributes of Provisionality, Progressive Evaluation and Premature Commitment are mainly reflected in the work of the computer performer–and in particular, those aspects of system behaviour that are defined through Supercollider code, and thus not accessible for inspection or modification during the performance. The structure of the interactive collaboration is thus bounded, in this work, by the compositional decisions made at coding-time and at performance-time.

The TouchOSC-based mobile control app offers a substantial contrast in the style of its interactive notation. Not visible to either the audience or the instrumental performer, it is a private notation designed to support performance decisions. As such, it offers a high degree of provisionality and progressive evaluation (with immediate effects on the shared notation and sound), and premature commitment only to the extent that the OSC parameters have been predefined. However, this latter decision is a key element of the interactive notation system. A regular tradeoff in the design of notations is the choice between Viscosity and Abstraction. More abstract notations allow larger changes to be made more quickly—for example, where traditional manuscript paper makes it laborious to transpose a composition, the same effect can be achieved instantaneously in most digital composition systems, by manipulating the abstraction of the musical key rather than the individual notes. The TouchOSC controller offers similar low-viscosity and high-abstraction functionality by directly controlling parameters of the composition that have effects over the continuing musical context rather than simply the current sound.

These choices of abstraction, in which the audience and instrumental performer are shown one view of the piece while the computer performer has another, offer a productive lens through which to unpick these conceptual understandings of musical structure within the context of improvised performance. The boundaries between the two notations can themselves be modified via SuperCollider, and it might be interesting to explore the extent to which the decisions made by each of the performers are more directly revealed to (or hidden from) those listening.

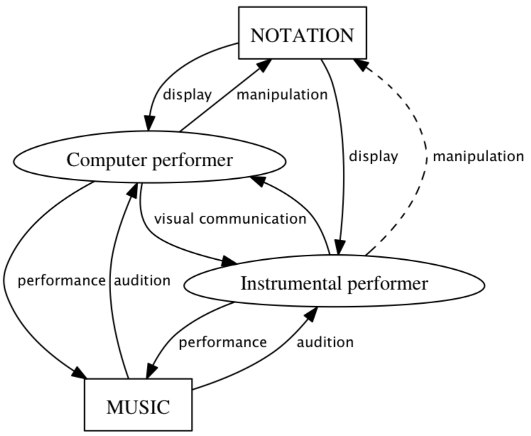

Figure 5: Interactions between performers.

5. Future Work and Conclusion

PitchCircle3D is a flexible tool for displaying and sharing live music notation—to performers and audience alike—in the form of a pitch clock, spiral and spiral helix. The software visually complements (shares) and notationally structures (as score) music performance, whether solo, collaborative, improvised or fully determined. PitchCircle3D's implementation in SuperCollider allows tight integration with audio synthesis, and the resulting real-time capabilities have affordances for live algorithmic computer music.

Ongoing software development of PitchCircle3D (whether or not used with the TouchOSC controller) is a shared endeavour, subject to informal 'alignment work' [20, 137] between the software's author and other performers. Investigation of the effectiveness of the environment for both flexible and specialist means of communication and sharing between performers and audience forms part of the research context in relation to the Cognitive Dimensions of Notations Framework. The extent to which the system can meaningfully be integrated into a flexible live coding environment is a related research question.

Future work will also investigate further options for collaboration between performers involving reciprocal musical interaction—including the ability of the acoustic performer to manipulate the notation and electronic music. Perhaps the highest constraint around PitchCircle3D is that its notations currently provide no rhythmic information, except through the real-time temporality of time points structuring the performance. Whilst such indeterminacy might be regarded as an in-built friction of the system as a performance notation, this approach maps well onto existing practices of musical improvisational. Nevertheless, future research will likely leverage further and alternate representations of musical parameters, including rhythm and other n-TET tunings, into the notation. In conclusion, explicit reference to musical structure is relatively rare in improvised music performance, and the notational experiments of PitchCircle3D and the accompanying TouchOSC controller suggest ways in which conceptually appropriate representational conventions might be developed further for sharing them.

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