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Musical Interpretation In Improvised Human-Machine Performance

by Benjamin Carey

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Abstract: The development of interactive performance systems is an active area of research in the field of live electronic music. Whilst various models and metaphors of interactivity have been proposed in the literature, the engagement of these systems in improvised performance remains under-researched. This paper explores the notion of musical interpretation in improvised human-machine performance practice from the perspective of a performer-developer. Through a consideration of the notion of the musical text, these creative artefacts and the performance practices they engender are situated within the context of interpretive musical practice. I argue that musical performances with these software systems may be seen as an instantiation of the combined musical ideas of the system developer, the musician navigating this space of ideas, and the live and interactive contributions of a machine to the performance. The paper concludes that the development of interactive software is akin to the creation a form of musical text.

Introduction:

The development of interactive performance systems is an active area of research in the field of live electronic music. Whilst various models and metaphors of interactivity have been proposed in the literature, the engagement of these systems in improvised performance remains somewhat under-researched. This paper explores the notion of musical interpretation in improvised human-machine performance practice from the perspective of a performer-developer. Through a consideration of the notion of the musical text, these creative artefacts and the performance practices they engender are situated within the context of interpretive musical practice. It is argued here that musical performances with these software systems may be seen as an instantiation of the combined musical ideas of the system developer, the musician navigating this space of ideas, and the live and interactive contributions of a machine to the performance.

This work is situated in the context of human-machine improvisation, a practice concerned with facilitating improvised relationships between instrumental musicians and interactive and autonomous computer music software. Sometimes referred to as live algorithms, such software systems are able to contribute to a live performance with a human improviser by combining real-time audio analysis with sophisticated generative algorithms used for responsive sound generation.¹ Whilst a full survey of such systems would be beyond the scope of this paper, examples of such an approach can be found in Lewis' *Voyager* system, Pachet's *Continuator* software, as well as in the research and practice of Young, Bown, Hsu, Lexer, Eldridge, and others.²

My own system, *_derivations*, is a semi-autonomous software system developed for use in improvised performances with instrumental musicians.³ The system listens to the

performance of an instrumentalist, employing a custom-designed *phrase matching* algorithm to relate the current performance of the improviser to a growing database of analysed *phrases* sampled from the musician's past performance. This form of "content-based music information retrieval" enables the software to use a musician's past and current performance as source material for its contribution to the improvised encounter.⁴ *_derivations* has been available publicly since 2013, and since its release it has participated in multiple performances internationally with a wide variety of musicians. These musicians have included myself, close collaborators, as well as complete strangers. Throughout my own doctoral research, I used the reflections on the development of this software to question the nature of the development and use of such systems in improvisatory contexts. As both a performer and developer of this software, I became interested in sociotechnical context of deploying such software in live performance with instrumental improvisers.

The practice of improvising with an autonomous or responsive software system raises issues concerning artistic authorship in this practice, as well as issues surrounding the status of the designed software artefact. In this practice, improvising musicians are often invited to participate in a performance by a system designer, who is very often present for rehearsals and performances with the software artefact. This multi-faceted creative practice articulates a nexus between musical improvisation and software development, and relies upon a unique combination of machine and human agencies throughout development, rehearsal and performance. Performances with such software systems are often given in highly curated performance scenarios, where performers are invited to collaborate with interactive software under the guidance of the developer. This system designer is often either an improviser and/or composer, whose musical ideas and sonic vocabulary is encoded into the system's design.

In this context, the capacity of the performer to improvise freely with a piece of software is therefore framed both by their interactions with both the software artefact and system designer. Given the complexity of this musical practice, some questions naturally arise: to what extent do the software developer and the artefact itself frame an improvisational interaction, and does this framing change the nature of the improvisational act? To answer these questions, we must first concern ourselves with the nature of improvised musical practice, and how this compares to interpretive musical practices.

Free-Improvisation and Interpretative Performance

In a freely improvised performance, improvising musicians develop musical structure in real-time without the presence of an overarching compositional framework. Also dubbed non-idiomatic improvisation, this type of performance distances itself from rules of melody, harmony and form in favour of free expression.⁵ Saxophonist Evan Parker has outlined this type of musical activity as his "ideal music," a form of music making that not only eschews the presence of a pre-defined musical text, but also places specific emphasis on the reliance upon the interpersonal relationships between like-minded musicians.⁶ These musicians improvise "freely in relation to the precise emotional, acoustic, psychological and other less tangible atmospheric conditions in effect at the time the music is played."⁷

This practice contrasts with interpretive practices in which the instructions provided by a composer govern music making, mediated through a musical text. The *Oxford English Dictionary* defines musical interpretation in part as: "the rendering of a musical composition, according to one's conception of the author's idea."⁸ In Davies' and Sadie's discussion of the term, interpretation refers to "the understanding of a piece of music made manifest in the way

in which it is performed.”⁹ These definitions consider the presence of an author, the existence of a musical work and the decisions made in relation to the author’s ideas as communicated in this work. In interpretive practices, the musical ideas of the composer are codified in a musical score, stated in a textual description, or transmitted orally to the performer. For Coessens, at one extreme the musical score can be seen as a form of direction or command.¹⁰ The author describes instruction as a target-oriented process, in that it “invites action to realise a fixed goal.”¹¹ On the other hand, the process of artistic expression is only partly target-oriented, as the interpretation of a musical text foregrounds the score as “material for performative action,” where value is to be found in the process of a musical narrative rather than a final product.¹² Even in traditionally improvised musical contexts such as jazz, the presence of a musical text, or referent, structures the improvisational activity, along with the melodic and harmonic conventions of the musical style.¹³

Given this above description, the term interpretation may be considered antithetical to the goals of freely improvised musical practice. In this context, the notion of interpretation as requiring something to interpret—that is, a pre-existing work communicated via a musical text—does not exist in any traditional sense. However, in the context of human-machine improvisation, where an autonomous and responsive musical system participates in a traditionally human-only performance scenario, the nature of both free improvisational practice and the identity of these systems come into question.

The Musical Text

For music as for other art forms, central to the notion of interpretation is the medium in which artistic ideas are transmitted. In a musical context, the medium is known the musical text or score. In musical interpretation, the performer must make decisions about how to successfully bring to life a composer’s ideas within the constraints communicated by this text. Musical texts take a variety of forms, from traditional Western notation to graphic notation, textual instructions as well as verbal and gestural instructions. A musical text might be fastidiously prescriptive by offering detailed symbolic instructions for the performer to follow, such as the complex musical notation of Brian Ferneyhough or the tablature notation of Aaron Cassidy.¹⁴ Other types of text might outline a framework that guide a performer’s musical decisions, such as in the score by La Monte-Young: “Draw a straight line and follow it,” or the instructions found in the works of Christian Wolff, such as: “a sound in a middle place, in some respect, of the sounds around it.”¹⁵ In addition, in so-called game pieces such as John Zorn’s *Cobra*, the musical text is manifest as a set of specific rules of interaction to be followed by a conductor and a group of improvising musicians.¹⁶

Graphic scores, rather than acting as direct instructions, often provide performers with a unique set of constraints that anchor their interpretive decisions. Such scores range from a set of symbolic instructions allowing for varying degrees of freedom within specific musical parameters, to objects of immense interpretive flexibility, such as Cornelius Cardew’s *Treatise*.¹⁷ In the latter case, interpretation is enacted by a performer in their development of personal rules and procedures in order to realise the musical work. Arrangements of graphic symbols such as those found in *Treatise* can be seen as the catalyst for the creation of a personalised musical grammar in response to the text. In his 1959 essay “The Poetics of the Work,” theorist Umberto Eco proposed the term “the open work” to describe musical works that left “considerable autonomy” to the performer as to how the work was rendered in performance. Eco refers specifically to works of Henri Pousseur, Pierre Boulez and Karlheinz Stockhausen, all of which give some freedom as to the musical structuring of materials by the performer. The author proposed that such works invite the performer to “make the work”

along with the composer, and that for the works “every performance *explains* the work, but does not *exhaust* it.”¹⁸

Regardless of the medium in which they are communicated, all musical texts contain some form of instruction for the performer to follow. However, as the examples above show, they also express context-specific assumptions about the role of the performer in bringing the work to life. Graphic notational practices and so-called open works often rely heavily upon the subjective interpretive faculties of performers, leading to a large space of possible renderings of a musical work. In addition, textual scores like those of La Monte Young and Wolff provide performers with a musical and interactive framework with which to construct the musical work. Such texts may direct the performer in the course of some pre-defined action, but may also leave out the specific means by which the action is achieved.

Despite their various manifestations, all of these types of musical text articulate the desired boundaries of a musical performance by implying various levels of musical freedom and constraint for performer(s) interpreting the work. They all involve some combination of explicit and implicit constraints from within which the musician makes decisions as to the best rendering of the work. Understanding a musical text as a set of explicit instructions, the term interpretation therefore implies a balance between fidelity to these instructions, and the injection of significant performative and stylistic understandings of the composer’s intentions. The relationship between adhering to and interpreting these instructions is dependent upon a variety of factors, which may include input directly from the composer during rehearsals, stylistic norms of the musical period in which the work was written, and the cultural conventions of contemporary performance practices. In this respect, the musical text communicates the requirements of the work as articulated by the composer, whilst the musical and cultural context in which the work resides provides further constraints on any reasonable and/or correct interpretation of it in performance.

Interactive Systems and Improvisational Performance

Acknowledging these specifics of both improvised and interpretive musical practice, we turn to the inclusion of interactive and autonomous systems into this performance scenario. The question we must ask here is this: is an improvised musical performance fundamentally different with the added presence of interactive musical software? I would suggest that the presence of such systems alters the way in which the musical context is perceived in performance, thereby changing the nature of the practice itself. The presence of a generative, responsive or autonomous musical system brings into focus the relationship between system designer and any human musician engaged in this practice. Here I take the view that such types of human-machine performance take place as part of a unique form of *sociotechnical framing*. The presence of an interactive system constrains and alters improvisational practice in some intentional way, due to its existence as a programmed entity. It is precisely because of the specific creation of a non-human actor (specifically the software) to be engaged with in performance, that the dual notions of interpretation and constraint in performance become relevant.

In human-only improvisational contexts, when performers encounter surprising musical materials and forms in performance these can be rationalised in terms of the skillset and abilities of their decidedly human counterparts. In general terms, human musicians approach an ensemble improvisatory context aware of the both the musical potential and cognitive faculties of their fellow human interlocutors. However, the same cannot reasonably be said of human-machine contexts. Any relationship that develops between a human and a

computer system during performance might be characterised as one of navigation, exploration and discovery. A system's behaviour will invariably indicate its musical and interactive constraints during the act of performance. However, for a musician unfamiliar with a piece of software and its behaviours, these constraints are often discovered throughout the act of performance. Indeed, it is often the case that the act of discovery becomes a dynamic element of a live performance. Furthermore, the more a musician spends time with such a system, the more such constraints are revealed. In this respect, initially unfamiliar performance paradigms can be conceptualised as a form of interactive material with which the human improviser engages.

However, in evaluating rehearsals and performances with such systems, Bown et al. have suggested that performers often engage with these systems to varying degrees of sympathy with their inherent capabilities. The authors highlight that at times there may be a disconnection between performer expectation of a system's abilities, and the system's actual response, and this is noted as an issue in assessing the effectiveness of such systems in performance: "They may play with too much expectation, posing phrases with the expectation of a response, or expecting things like rhythmic entrainment or the anticipation of a developed trajectory such as a crescendo."¹⁹ Whilst some systems may be programmed to interact with musicians in such a way, others may not be. If, for example, a piece of software is not capable of following or interpreting a musician's rhythmic pulsations or dynamic changes as expected, the musician may be disappointed with the interaction, and the performance may therefore suffer as a consequence. Given this, it is clear that a performer's knowledge of the software's affordances, whether in advance or discovered through interaction, is often consequential to the outcome of any live performance.²⁰

Development as Sociotechnical Framing

Naturally, a software system's existence as a programmed entity highlights the role of the human actor responsible for its design. In this performance practice, it is the system designer who proposes the musical scenario of human-machine performance to improvising musicians, either explicitly (via invitation) or implicitly (through software distribution). Regardless of how this proposition is made, the system designer in this context, acting as an author, proposes a musical framework to be navigated in performance. The placement of one or more human improvisers in such a performance context should therefore be understood as a form of sociotechnical framing. The programmer is no longer only the author of a piece of software, they are also responsible for the framing the musical and interactive context in which both the human and machine engage. This framing may also be considered a non-trivial act of artistic authorship.

Part of this framing process may involve the choice of musician or musicians to engage with the software, how much information is given to them about the software's affordances, and where and to which artistic networks the software is distributed. In some cases, software behaviours may have been explained to a musician prior to an interaction, whilst in others they may be left to the improviser to be discovered during performance. In addition, repeated experiences with the software by a performer are often coupled by informal discussions with the developer about their experiences, adding to their knowledge of the software's affordances. The performer's prior understanding of the precise abilities of the software—whether directly responsive, analytical, generative or otherwise—will no doubt affect the perception of their relationship to the machine in performance. Bown et al. note this in their analysis, reflecting on the influential nature of these specific details upon the musician's understanding of the interactive context: "if a musician is given more specific

information about exactly what is being listened to (pitch relationships, timbral characteristics), or details about how the system uses this knowledge in its decision-making, we might expect that the musician's performative interaction with the system would be coloured by this knowledge."²¹

In the case of my *_derivations* software, individual interactions with musical collaborators have varied in this respect. To date, performances with the software have included ongoing collaborations, one-off performances as well as third-party organised performances without my direct participation. With respect to recent collaborations, improvisers Joshua Hyde (saxophone), Zubin Kanga (piano), Teresa Connors and Ellen Waterman have all either experienced *_derivations* in performance, or discussed the software with me in depth in advance of their initial encounter with the system in performance.²² These three musicians therefore came into the environment with a conception of the interactive context informed by my ideas as a developer. Working with these musicians, discussions on the reasoning behind programming decisions, the intricacies of certain processing modules and the inner workings of the matching algorithm were commonplace. As such, direct experiences of the performers with the software were supplemented by contextual knowledge of the software's affordances.

In addition to the above collaborations, two encounters with musicians Evan Dorrian (drums) and Antoine Läng (voice) were characterised by a lack of sustained exposure to the *_derivations* musical system prior to performance. Instead, an in-situ discussion on the basic premise of the software just prior to the performance framed each interactive encounter. Neither of these musicians had any prior experience with the *_derivations* system, nor any other interactive performance system of this type. Despite the spontaneity of these encounters, common to both Lang's and Dorrian's experience with the software was the curatorial context in which they engaged with the software. Alongside two other performers, Dorrian was invited to participate as part of a weekend "hack-together" event that involved numerous developers working with algorithmic and interactive software. Similarly, Läng performed with *_derivations* as part of an impromptu grouping of instrumental improvisers and software developers. The event was the performative showcase for the Biome Symposium—an interdisciplinary research symposium surrounding mathematical approaches to various creative practices.²³

Third party performances with *_derivations* have been many and varied. Since the launch of the *_derivations* website in 2013 the software has been available for free download and use, facilitating many performances and recordings with the software without any direct input from myself.²⁴ To facilitate self-guided user interaction with the software, five detailed documentation videos were designed to familiarise performers with the software, and made available on the website. These videos exist both as a communicative tool and a how-to guide for musicians wishing to interact with *_derivations*. On a practical level, the videos explain the various technical functions of getting started performing with the software. These include instructions on how to get sound in and out of the software, what the various sound analysis algorithms are capable of, as well as detailed descriptions of the electroacoustic treatments the software uses in order to respond to a musician live in performance.

As an improvisational system, *_derivations* is designed to be somewhat malleable with respect to its interactive and sonic response. Performers, acting as users of the software, are given a choice as to what kind of material is made use of during performance, as well as how it may be manipulated during an improvisation. As a result, whilst the videos de-mystify for the performer the means by which the software interacts in performance, the openness of

the system also allows the performer some freedom as to how the system may behave on stage. These videos, and the accompanying website, therefore serve a dual role with respect to the notion of authorship and interpretation in this performance practice. As a user, the performer is given control and freedom over some of the eventual workings of this interactive artefact. However, it is clear from these videos that there are necessary constraints to the interactive paradigm, as evidenced by the clear design choices made by myself as the developer. In addition, by de-mystifying the underlying processes at work within the system, these videos (spoken by myself as the software's designer) further solidify my role as author of the interactive context in which the musician engages.

Software as Musical Text

System designers hold personal musical goals and stylistic preferences, many of which are subtly or overtly manifested in the behaviour of their systems in performance. Although these musical systems are often capable of surprising yet musically coherent results, their capabilities should be understood as the result of specific, programmed decisions of a human author external to the performance-time interaction. In the *_derivations* system, the sound generation and processing capabilities of the system enforce certain aesthetic boundaries on the improvised performance. The system lacks melodic and rhythmic awareness in its listening algorithms, and the electroacoustic means by which sampled materials are combined inevitably limits the stylistic horizons navigable by musicians interacting with the software. Whilst neither the programmer nor the software has made explicit requirements of a musician's performance, the programmed dynamics of *_derivations* ultimately contributes to framing the musical and interactive boundaries of any performative encounter. These dynamics act as interactive constraints on an improviser's performance. In this context, the interplay between *_derivation's* generative, interactive and sonic vocabulary reveal my aesthetic intentions in the creation of the musical system.

For Coessens, an important function of a musical text or score is that it organises action in some meaningful way. This type of text also “reveals underlying ideas in a coded format”—the ideas of the author—rather than simply codifying instructions.²⁵ Although not communicating explicit requirements to the performer, the sociotechnical context proposed by the developer of an interactive performance system clearly frames the context of an improvised encounter. The presence of an autonomous machine in an improvised scenario codifies the developer's broad ideas about human-machine performance. In addition, the choice of algorithmic, sonic and interactional capabilities of these machines also organises musical action in meaningful ways. By navigating, exploring and discovering the boundaries of the interactive space proposed by an interactive musical system, the performer is engaging in a form of interpretation. To borrow Coessens' term, as “material for performative action,” the interactive constraints of a system like *_derivations* help frame the sociotechnical relationship that develops between a musician and a software system on stage.

It may therefore be argued that the development of the software is akin to the creation a form of musical text. This text is not dissimilar from both the graphic and algorithmic textual scores discussed previously, and may be considered as an example of what Eco has called an open work. Henri Pousseur, as quoted in Eco, describes his work *Scambi* “not so much as a musical composition but as a *field of possibilities*.”²⁶ Whilst in Pousseur's work the performer is explicitly asked to exercise choice from fixed materials, I would argue that the term “*field of possibilities*” equally describes the function of the musical and interactive constraints embodied within an interactive performance system. However, rather than embodied in a graphical or textual representation, the constraints on a musician's

performance are interactively instantiated through performance with the software. As discussed above, certain modes of performance will ultimately reveal themselves as more in tune with the affordances of a particular software system than others, and may also have been communicated as such by the developer prior to an interaction. Exhibiting agency within a musical performance, these systems provoke, shape and contribute to a musician's improvised trajectory. These behaviours are of a programmed nature, regardless of the degree of autonomy displayed during performance, and therefore express the compositional concerns of their authors.

Conclusion

Musical performances with interactive performance systems may be seen as an instantiation of the combined musical ideas of the system developer, the musician navigating this space of ideas, and the interactively instantiated contributions of a machine to the performance. It is precisely because such systems are imbedded with these subjective attributes that performers in this context necessarily engage in a form of interpretation. Although their moment-to-moment performance may be freely improvised, the framing of the interactive context suggests a sociotechnical framework that requires interpretation in performance. From this perspective, any consideration of a musical text must take into account the entire performance scenario. The musical text is, in effect, the boundaries and constraints of such a human-machine musical interaction as influenced by the machine's perceived capabilities. Navigating these possibilities in a truly interactive sense is the task laid out for the musician. By navigating this space proposed by the designer, the musician is engaging in an interpretive act.

Endnotes

All URLs accessed late 2018.

¹ Tim Blackwell and Michael Young, "Live Algorithms," *Artificial Intelligence and Simulation of Behaviour Quarterly*, 122 (2005): 7-9.

² George Lewis, "Too Many Notes: Computers, Complexity and Culture in Voyager," *Leonardo Music Journal*, 10 (2000): 33-39; François Pachet, "The Continuator: Musical Interaction With Style," *Journal of New Music Research*, 32.3 (2010): 333-341; Michael Young, "NN Music: Improvising with a 'Living' Computer," in Kronland-Martinet Richard et al., eds, *Computer Music Modeling and Retrieval Sense of Sounds* (Berlin: Springer-Verlag, 2008), pp. 337-350; Oliver Bown, "Experiments in Modular Design for the Creative Composition of Live Algorithms," *Computer Music Journal*, 35.3 (2011): 73-85; William Hsu, "Strategies for Managing Timbre and Interaction in Automatic Improvisation Systems," *Leonardo Music Journal*, 20 (2010): 33-39; Sebastian Lexer, "Piano+: An Approach Towards a Performance System Used Within Free Improvisation," *Leonardo Music Journal* (2010): 41-46; Alice Eldridge, *Collaborating With the Behaving Machine: Simple Adaptive Dynamical Systems For Generative and Interactive Music*, doctoral dissertation (Brighton: University of Sussex, 2008), reproduced on https://www.academia.edu/1996170/Collaborating_with_the_behaving_machine_simple_adaptive_dynamical_systems_for_generative_and_interactive_music.

³ Benjamin Carey, *_derivations and the Performer Developer: Co-Evolving Digital Artefacts and Human-Machine Performance Practices*, doctoral dissertation (Sydney: University of Technology, 2016), reproduced on <https://opus.lib.uts.edu.au/handle/10453/43452>.

⁴ Michael Casey et al., "Content-Based Music Information Retrieval: Current Directions and Future Challenges." *Proceedings of the IEEE (Institute of Electrical and Electronics Engineers)*, 96.4 (2008): 668-696, reproduced on <http://doc.gold.ac.uk/~mas01cr/papers/procieee2008/cbmir.pdf>.

⁵ Derek Bailey, *Improvisation: Its Nature and Practice In Music* (Cambridge, MA: Da Capo, 1993), p. 81.

⁶ *Ibid.*, 81.

⁷ *Ibid.*, 81.

⁸ *Oxford English Dictionary Online* (Oxford: Oxford University Press, 2015).

⁹ Davies Stephen and Sadie Stanley, "Interpretation" (2001) in *Grove Music Online: Oxford Music Online* (Oxford: Oxford University Press, ongoing).

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- ¹⁰ Kathleen Coessens, "The Score Beyond Music," in Paulo de Assis et al, eds, *Sound and Score: Essays on Sound, Score and Notation* (Leuven: Leuven University Press, 2013), p. 178.
- ¹¹ Ibid., p. 179.
- ¹² Ibid., p. 179.
- ¹³ Jeff Pressing, "Cognitive Processes in Improvisation," in Ray Crozier and Anthony Chapman, eds, *Cognitive Processes in the Perception of Art* (Holland: Elsevier, 1988), pp. 345-363.
- ¹⁴ Tim Rutherford-Johnson, "A Journey to Aaron Cassidy's Second String Quartet," *NewMusicBox* (9 Feb 2011), <http://www.newmusicbox.org/articles/A-Journey-to-Aaron-Cassidys-Second-String-Quartet/>.
- ¹⁵ La Monte Young, *An Anthology of Chance Operations* (New York: La Monte Young and Jackson Mac Low, 1963), unpaginated, reproduced on <http://ubutext.memoryoftheworld.org/AnAnthologyOfChanceOperations.pdf>; Christian Wolff, *For 1, 2 or 3 People* (New York: Edition Peters, 1964), p. 3.
- ¹⁶ John Zorn, *Cobra* (Switzerland: Hathut, 1984).
- ¹⁷ Cornelius Cardew, *Treatise* (Buffalo: Gallery Upstairs Press, 1967).
- ¹⁸ Umberto Eco, "The Poetics of the Open Work" (1959), in Christoph Cox and Daniel Warner, eds, *Audio Culture* (NY: Continuum, 2004), pp. 171.
- ¹⁹ Oliver Bown, Benjamin Carey, et al., "The Musical Metacreation Weekend: Challenges Arising From the Live Presentation of Musically Metacreative Systems," in Phillippe Pasquier et al, eds, *Musical Metacreation: Papers from the 2013 AIIDE Workshop* (Boston, MA: AAAI Press / Northeastern University, 2013), p. 31, reproduced on <https://www.aaai.org/ocs/index.php/AIIDE/AIIDE13/paper/view/7444>.
- ²⁰ On the concept of "affordances," see Donald Norman, *The Design of Everyday Things: Revised and Expanded Edition* (NY: Basic Books, 2013), p. 11.
- ²¹ Ibid., p. 32.
- ²² Recordings of these performances can be accessed at <https://vimeo.com/55189188>, <https://vimeo.com/128663085>, <https://soundcloud.com/divat-t/connors-derivations> and <https://soundcloud.com/divat-t/waterman-derivations>, respectively.
- ²³ The Biome Symposium was held at the University of Sydney on 18 August 2012. The performance event formed part of the art exhibition that ended the one-day symposium; see http://s-architecture.blogspot.com/2012/04/s-architecture-fwd-call-for-papers_10.html
- ²⁴ See <http://derivations.net>
- ²⁵ Coessens, p. 178.
- ²⁶ Eco, p. 168.