



xCoAx 2019

Conference on Computation,
Communication, Aesthetics & X

Milan, Italy

Gordan Kreković

gordan.krekovic@visagetechologies.com

Visage Technologies,
Zagreb, Croatia

Antonio Pošćić

antonio.poscic@gmail.com

Unaffiliated,
Zagreb, Croatia

Modalities of Improvisation in Live Coding

Keywords

live coding
improvisation
composition
music aesthetics

Live coding is a practice of computer programming used to create music and digital media that strongly relies on improvisation. While live coding, as a relevant form of contemporary artistic practice, is a lucrative research topic, improvisation in this interdisciplinary setting is scarcely systematically explored. This paper investigates modalities of improvisation and its relation to composition in live coding from multiple viewpoints. First, we provide an overview of improvisation in its historic and contemporary contexts identifying common traits of traditional, live electronics, and computer-aided improvisation. Then, we discuss and categorise modalities specific to live coding based on the nature of pre-written code and the types of real time interventions. Besides theoretical views, we present a case study – our practical experience with one of the improvisational modalities used to create music for a contemporary choreography.

1 INTRODUCTION

The relationship between improvisation and composition in the context of music has been a long and strenuous one. Especially when Western music traditions are concerned, composition was often ascribed characteristics that elevated the approach and methodologically elaborate techniques above all else (Larson 2005). Improvisation was, in contrast, seen as a thing of itself, an “irrational” and unstructured form of expression. Similarly, while improvisation in music can be traced back to traditions dating before the medieval period and even if composers like Mozart and Beethoven used variations extensively, in academic texts it was frequently shunned, ignored, and held to lower standards. It was considered a parlour trick that sat on the opposite side of the semiotic perfection and purposefulness of composed music (Nettl 2013). These academics will often resort to Platonic philosophy, demeaning the sensuous and undisciplined (improvisation) in favour of the rational and the controlled (composition).

That stance changed considerably in the latter part of the twentieth century as contemporary composers began incorporating improvisation in the core of their work (MacDonald et al. 2012) and developed techniques and approaches like aleatory music (Hoogerwerf 1976). Simultaneously, popular jazz idioms slowly but surely made their way into the hermetic spheres of academia via cultural appropriation (Born and Hesmondhalgh 2000). Recently, improvisation and composition have become viewed by researchers as deeply connected members of a continuum and correlative relationship instead of two sides in conflict (Nettl 1974). In that sense, improvisation becomes a precondition for all composition processes (Wilson and MacDonald 2017).

Outside of the Western sphere, improvisation was and remains an important part of religious and transcendental rituals (Hodgkinson 2016, Houseman and Severi 1998). For practitioners of improvisation in the fundamental sense, these processes come naturally, without primary aesthetic or artistic consideration. Still, they produce valuable artistic and highly aesthetic results.

Today, improvisation can be heard in various musical styles and is often meshed with composition. Outside of particular genres like free jazz and free improvisation, which both hold improvisation at the core of their creative processes, it is also a relevant factor in certain styles of electronic music, pop, rap, etc.

In the field of electronic music, one type of creative practices especially relies on improvisation: live coding. The art of using computer programming, algorithms, and code as makeshift scores and music creation tools is built around improvisation, with musicians most often writing code in real time during live performances. While live coding is a productive and rich field of research – with researchers considering both technical and artistic implications of the practice – the continuum of improvisation and composition within it is scarcely explored.

The focal point of this paper is on modes of improvisation in live coding. A case study based on a real life live coding experience is presented, delineating the influences of improvisation, composition, and their amalgamations in the interdisciplinary setting of live coding. To support our analysis, we first explore different aspects and characteristics of improvisation, providing a brief overview of the relationship between improvisation and composition. Both historical and contemporary implications are considered, but with a focus on the latter. We also present existing studies in the field of live coding that might indicate the position of improvisation as well as stylistic limitations related to technologies and well-known improvisation and composition techniques.

Finally, we outline future work that, based on the premises presented in this paper, will seek to challenge (mis)conceptions about improvisation in live coding and, more importantly, will try to employ human-computer interfaces and modified live coding environments to improve the improvising experience.

2 A CASE FOR IMPROVISATION

2.1 A Brief History and Ontology

In his book *Music and the Myth of Wholeness* (Hodgkinson 2016), experimental music composer and performer Tim Hodgkinson notes:

“ Perhaps this is the moment for a hymn to improvisation, first, because an improvised action cannot, by definition, be repeated. Improvisation directly attacks the formula what is must be, and says instead, what is ... could have been otherwise ... and certainly will be otherwise. Second, improvisation is against plans and automatism. We see distinctive traces of indeterminacy throughout the spectrum of artistic production in self-consciously historical societies. The generative importance of the improvisational and the accidental enters everywhere, even when not explicitly presented as such. In our own culture this becomes explicit as artistic method in the early twentieth century.

For Hodgkinson, improvisation is at the heart of all creativity in music, be it in evidently improvised or composed contexts. He attributes almost transcendental characteristics to improvisation, which he frames into a theory of the “aesthetic listening subject”. Indigenous cultures, like the Tuvan tribes in Siberia, he argues, employ improvisational practices in their everyday rituals. Their purpose is healing and not art. That is to say, for Hodgkinson, improvisation is a part of the human experience regardless whether it is intentional or not. Yet, it was only during the beginning of the twentieth century, spurred on by expressionist art and Dadaism, that the practice became self-aware and codified into “free music”.

Apart from Hodgkinson who presents a comprehensive overview of improvisation and considers its philosophical, religious, and musicological implications, notable researches and resources on the subject are (Net-

tl 1974), (Chase 1988), and (Benson 2003). While these texts differ in the approach and classification of improvisation, they reach similar conclusions.

Historically speaking, the actual emergence of a freely and collectively improvised music is indebted to African-American music and its development in specific geographical and stylistic loci like New Orleans, bebop, etc. These developments coincided with rising interest in indeterminacy, open form, and aleatory techniques in European composed music. This ultimately separated free improvisation from the jazz idiom as part of which it had developed as a practice.

2.2 Contemporary Practices

Contemporary free improvisation can be, almost ironically, considered a genre with specific tropes, idioms, and constraints that is ultimately ruled by a certain stylistic determinism. As we will show in later chapters, there is evidence that this might not be a coincidence and instead a potential common trait shared between improvisation-based practices (e.g. live coding). In fact, John Cage's most notable critique of improvisation (Feisst 2009) is that there is no true (collective) improvisation and that musicians will undoubtedly always find themselves in routines and repeated patterns. In other words, improvisation will always generate its own antithesis.

But it is exactly this aspect of improvisation that connects it to composition. In that sense, we can say that improvisation can both be viewed as spontaneous composition and, when distilled to its core processes, a part of each compositional approach (Sawyer 1999). Continuous and repeated improvisation can become ingrained, classified, and formalized. Or, if we reverse the flow of information, we can consider composition to be built on top of quiet, non-performative improvisations in the mind of the composer.

In the context of contemporary free jazz and improvisation, we can identify three types of approach to improvisation and composition. First is the "classic" approach characteristic of post-bop and similar styles closely connected to traditional forms of jazz. Here, most music is composed, with well-known techniques used repeatedly and extensively. A common style can usually be identified. Improvisation is pushed to solo sections and phrasing variations, but all within a well-defined and static framework. Additionally, the improvisations themselves usually follow a certain set of patterns (Martin 1996).

The second approach can be found in contemporary free jazz, championed by the likes of Chicagoan Ken Vandermark, an often used approach is to employ precomposed themes and sections which the musicians then evolve and improvise against during live performances. These themes can serve as starting points for collective improvisations, meaning that while certain harmonic, rhythmic, and melodic characteristics will be shared between performances, the structure, overall tone, and final form of the compositions will vary greatly. While based on a different set of concepts, we can include techniques like John Zorn's game pieces (Van der Schyff 2013) or some of Anthony Braxton's concepts in this category as they lay

out very specific theoretical music frameworks that then serve as basis for improvisations.

Finally, the third approach is rendered through true free improvisation or completely spontaneously created music. These performances should, ideally, be completely unique and can be the result of the first meeting of musicians. There are no pre-imposed themes or rules and instead the performance relies on the shared musical connection between performers and their ephemeral interactions. Practice shows that, because the musicians are rarely blank slates, even free improvisation in the fullest sense can become ruled by the musicians' previous experiences, shared performances, etc. Many musicians note how difficult it can become not to repeat previous phrases and interactions during repeated performances with the same opposite players (Hallam et al. 2011).

As we will note in the third chapter, these three concepts can also be applied to live coding. Additionally, while an interesting subject, the implications of recorded improvisations will not be discussed in this paper.

3 THE NATURE OF IMPROVISATION IN LIVE CODING

The origins of improvisation in live coding are, in conceptual and poetic terms, related and akin to the development of live electronics. In his paper *Gentle Fire: An Early Approach to Live Electronic Music* (Davies 2001), Hugh Davies traces the history of live electronics through the experiences of his group Gentle Fire, dating back to the 1960s. He outlines the basic processes and motivations behind the music and explores how the semantics and practices revolving around live electronic music evolved. Many of these thoughts and concepts can be applied to live coding.

Throughout, Davies underlines the importance of improvisation or spontaneous performative actions that influence the music and compositions. Additionally, the importance of Davies's work is extended to traditional improvisation as he was a part of The Music Improvisation Company in which he collaborated with leading free improvisation musician and proponent Derek Bailey. The group's focus was on meshing live electronics improvisation with existing free improvisation techniques. His work, along with the work of luminaries like John Chowning (Zattra 2007) and Peter Zinovieff (Risset 2007) are the earliest examples of improvisation being featured as part of the live performance of electronic music. In that sense, we can see these and similar related works as precursors of live coding.

On the other side of the spectrum, and contrasted to today's notion of "laptop music" which carries mainly negative connotations related to the phenomenon of music prepared in advance and only reproduced in a live environment on stage (Cascone 2002), some of the earliest attempts of using computers for improvised music can be traced to practices related to "laptop ensembles". Laptop groups like The Hub and EMU ensemble, both dating to the 1980s, used laptops to create collective improvisations (Knotts and Collins 2014).

The origins of live coding, in a narrower sense and as we understand it today, can be traced to the early 2000s and works such as (Collins et al. 2003). In this seminal research, improvisation is considered to be an integral part of live coding from its onset. When looking at recent developments, notable is the work of Thor Magnusson who argues for live coding and algorithms as extensions of the musical score (Magnusson 2011). Here, improvisation becomes imbued in the musical score and the lines between improvisation and composition are blurred. For Magnusson, improvisation in live coding is the equivalent of real-time composition:

“ Live coding is the offspring of the two strong traditions described above: the formalization and encoding of music, often for machine realization, on the one hand, and the open work resisting traditional forms of encoding on the other. Live coding is a form of musical performance that involves the real-time composition of music by means of writing code.

Elsewhere, researches such as (Freeman and Van Troyer 2011; Wilson et al. 2014) all view live coding as primarily an improvisational technique or a fusion of both improvisation and composition. These researches serve as evidence of notions presented in the previous chapter: improvisation and composition are ingrained and interdependent. As will be explored in the following chapter, live coding can combine several degrees of composition and improvisation techniques, but is ultimately reliant on improvisation during live performances.

While it is primarily viewed as a technique with the potential to influence live performances and change dynamics attributed to mainstream electronic performances deemed to be otherwise static – musicians just pressing “play” – live coding must also be viewed through the prism of influencing and shaping the creative processes of musicians (Magnusson 2014). In this sense, it is interesting to consider whether live coding imposes its own set of preconceptions and stylistic trademarks similarly to what can be observed in traditional free improvisation or whether it can, through various mechanisms, free the performers from exactly these learned and repeated behaviours.

3.1 Improvisation Practices in Live Coding

Analogous to the contemporary practices in free jazz, free improvisation, and similar genres, we can say that improvisation appears in three forms in live coding, depending on the level on which improvisation occurs.

The purest type of improvisation in live coding is when code is written from scratch during live performances. In this case, the musician or coder forgoes any preparations and relies solely on spontaneous ideas and thoughts. This modality of improvising coincides with the processes in traditional free improvisation. Obviously, just like in the case of free improv, the musician is influenced by previously written code, which they can recollect, earlier experiences, and expectations imposed by the tool it-

self. As it's demonstrated in some works related to visual programming in music (Pošćić and Kreković 2018), programming for music is often used by looking at tutorials and code examples on the internet. This learning process might significantly influence the later creative output of a musician.

The second type of improvisation in live coding relies on prewritten or composed music. In this case, the code that generates the music is prepared and written in advance of the actual performance. During the live performance, the musician makes interventions in certain segments of the code and thus modifies the music in real-time. This approach coincides with the traditional position of improvisation in jazz subgenres like hard bop. Even though it might seem restrictive at first glance, and unlike improvisation in bop, the possibilities of improvisation based on the set code are limitless as there are no imposed restrictions on how much of the code the musician can modify.

Finally, the third modality of improvisation in live coding presents a middle road between the two previously described options. Here musicians prepare snippets or segments of code in advance, either as starting points for spontaneous compositions or building blocks to be used throughout. We can say that these blocks of code represent “themes” that then get evolved, elaborated, and chained to each other. Based on the available body of work in live coding, it appears as the most commonly used modality.

In all of these cases, the creative process is largely influenced by the characteristics of the tool of choice. Notable live coding environments like TidalCycles and Impromptu seem to impose a certain aesthetic lineage on performances and works created in them. Simultaneously, tools that employ contrasting graphical paradigms like the Threnoscope (Magnusson 2014) induce different stylistic traits in the works produced in them. Whether these phenomena are direct results of unavoidable characteristics of these tools or consequences of more complex socio-cultural interactions (like learning methods and influence through communities) is an interesting question, but beyond the scope of this paper.

4 AN INVESTIGATION THROUGH PRACTICE

As an extension and complementation to a theoretical view on improvisational live coding practices based on pre-existing parts of code, this study includes investigated possibilities, generalized observations, and experienced implications obtained through a practical part of the research. Following the paradigm of improvisation grounded on modifying and triggering prepared code, one of the authors composed music for a full-length contemporary choreography using TidalCycles, a textual programming language and an extensive library for live coding (McLean and Wiggins 2010). The selection of the tool implied the pattern-based approach which significantly influenced various conceptual, aesthetic, and practical aspects. The hands-on experience enabled us to investigate the scope of improvisational interventions and their consequences on the musical aspects, but also on the performance as a holistic multimedia entity.

4.1 Motivation and Hypothesis

The main expectation from preparing code segments in advance was to create a plateau, a mature starting point that transitions the focus from building basic elements to handling complexity and nuances during live performances. Obtaining aesthetically refined results by writing code from scratch requires experimentation and takes time. In the context of accompanying dancers and video projections, timing in music is not arbitrary, but it depends on other performative elements. Live coding based on prepared code segments was expected to offer an appropriate balance between the pre-arranged dramaturgic evolution, pre-composed themes, and intentional occasional synchronicity between dance and music on one side and spontaneity, adaptability, and unexpected interactions on the other. Therefore, the aim was to prepare a certain set of musical ideas in advance and use them as an improvisational material through modifications, reductions, and extensions.

Code development began soon after the choreographer and the dancers started experimenting with dance movements and overall atmospheres. A vague outline of dance sequences inspired the initial organization of pre-defined musical phrases which were expected to evolve during time.

During the course of time, the dance sequences became longer, more structured, and more nuanced; some sequences were abandoned, while several new parts emerged to fill gaps. The similar approach reflected on the music creation process which—thanks to the established paradigm—allowed a lot refinements, evolution of complexity, cumulative definition of aesthetic consistency, and finally, iterative alignments with choreographic, scenographic, and visual elements of the performance.

4.2 Scope of Improvisational Interventions

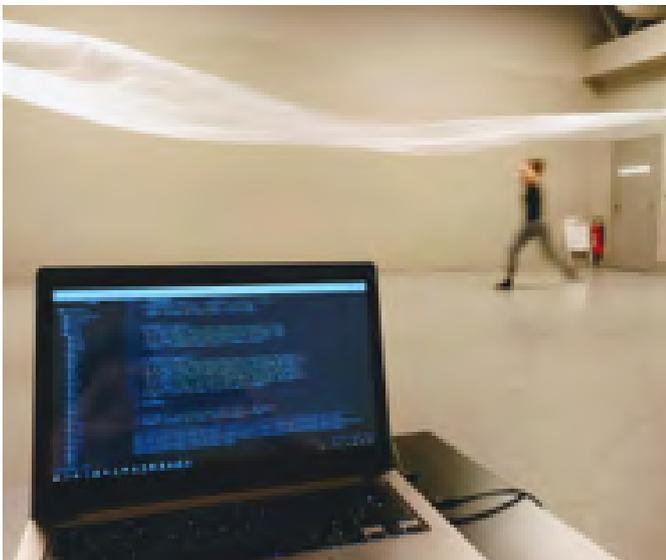


Fig. 1.
Live coding for contemporary
choreography

Timing is the first improvisational operation that is specific for being a variable aspect of live coding that exists even when the code stays unchanged during performance. If not explicitly chained in advanced, blocks of code stay independently and produce cyclic patterns when triggered. In the context on musical aesthetics built on repetitions, isorhythms, and changes, a possibility of controlling pattern duration and timing is an operative aspect of influencing the musical composition on the meso and macro time scales (Roads 2004). Additionally, such a possibility facilitates the coordination between music, dance, and multimedia elements. Longer repetitions during rehearsals allowed dancers to accommodate to certain musical moods and develop the quality of movement appropriate to those music phrases. When the dance sequences became more matured and defined, manual execution of code blocks had an important role of maintaining the overall flow of the performance – sometimes the progression of music waited for appropriate changes in dance, while in other cases the dancers were triggered by changes in music. Aside from all conceptual and practical benefits, when it relates only to executing unchanged code, the intentional variability of timing can be barely considered as an improvisational intervention.

Regarding the actual changes in the code during live performances, they can be categorized to 1) modifications on the sound object level, 2) modifications on the pattern level, and 3) creation of new patterns.

Modifications of sound objects refer to changing particular elements of music patterns. In practice, these elements are sound samples and they “generalize the traditional concept of note to include complex and mutating sound events on a time scale ranging from a fraction of a second to several seconds” (Roads 2004). Subsequent modifications of sound objects break the continuity of repetitions and allow improvised transformations of musical phrases in real time. In this context, timing is crucial, because the changes are not audible immediately, but only after the following cycle starts. The possibility to control sound objects combined with deliberate timing brings live coding closer to the experience of playing a musical instrument, as sound objects relate to melodies and textures at the compositional meso level. In practice, this technique has been applied to tonal phrases in which the changes of leading tones created melodies. An example is a repeating arpeggio whose highest tone changes in each repetition following a melodic line, while other tones stay the same. Another purpose of this technique in our experimental practice was to mitigate monotonicity of periodic sonic textures created by chaining different sound objects with noisy qualities. Although it could have been achieved programmatically by the random selection of sound objects, manual interventions allowed more adequate reactions to the situations on the scene and more active engagement by the musician.

Modifications on the pattern level affect the whole patterns, as they usually target functions that control the sample playback parameters, sound effects, and the pattern’s structure. By adding, deleting, substituting, and re-parameterizing those functions, the musician can significantly reshape

the building sonic material. The changes introduced this way were very important in our practical setup, since the set of underlying sound samples was intentionally reduced to a sonically consistent and hermetic scope. One of the reasons for such a reduction was to motivate the exploration of live coding possibilities, while maintaining the conceptual consistency. Consequently, modifications on the pattern level became the main mechanism for introducing gradual advancements that perceptually differentiated the generated music from the raw building material. They served as a mean of sonically significant interventions during live performances that were sometimes applied on different simultaneously playing patterns in quick iterations to totally dissolve repetitions into lively and organic transitions between sonic variations.

The third mode of intervention is writing new code segments from scratch. The fact that we opted for a paradigm based on pre-existing code did not prevent us from adding new code during live performances, as that approach offered the maximal spontaneity and the widest range of expressive possibilities. Moreover, since there were a lot of already prepared code segments, their execution created some additional time to write new code while existing was producing music. It turned out that such a practice usually resulted with changes that were not expected by the dancers. Namely, the dancers were used to known material and its incremental changes, so any significantly different pattern positioned them in a new musical context. As the dance sequences became more defined and predictable during rehearsals, the range of improvisational interventions by adding new code also decreased. However, live coding from scratch remained as a useful mechanism for breaking excessive repetitions and for introducing new musical content in cases when dancers prolonged their sequences either deliberately or forced by specific situations on the scene.

4.3 Repeatability and Accumulative Nuancing

Through the previous discussion about improvisational possibilities, we touched upon the fact that the complexity of musical content increased by accumulating changes introduced following the improvisational practice during rehearsals and live performances. This was possible because of the exact repeatability achieved by saving the changed code. While it may seem as a trivial consequence of a textual editor's basic functionality, the possibility to exactly store results of improvisational interventions and use them as a starting point for future interventions is an idiomatic and unique characteristic of live coding.

The reason is that the information is stored at the first level of mapping musical ideas into music – on the code level where only the functions for creating patterns and structures exist. It is before actual patterns are formed, before they trigger sound objects, before sound objects are reproduced and processed, and before a resulting audio signal is transformed to sound. This unique situation is a result of the fact that program code almost directly represents any algorithmically formed idea. When playing a

musical instrument, ideas are first converted into physical actions and the first level at which the information can be stored is a trace of those actions, such as MIDI signal. There is no way to capture the idea earlier, because it has been already transformed to actions before being expressed in an algorithmic form. While it is possible to modify MIDI, such modifications follow a different paradigm from the one used to capture the actions for the first time. It is not possible to improvise by editing the MIDI content in the same way as the musician has improvised when the content has been created. On the other hand, in live coding, those paradigms are unified - creation and modification are both done on the level of algorithmic ideas.

The specificities of the medium also entail a consensus about valorisation. In a traditional sense, improvised music is valued for being unique and its reproduction on the performative level seems absurd. In fact, it is so absurd that the notion of such a note-for-note copy could be a strong statement itself, as demonstrated by Mostly Other People Do The Killing and their album *Blue* which is a remake of Miles Davis' album *Kind of Blue* (Corotto 2014). On the other hand, the reproducibility in live coding is an idiomatic characteristic that is achieved by a trivial action of saving the changes in the textual editor. However, by that action, results of improvisational interventions become a part of the algorithmic corpus and lose the quality of uniqueness. When such improvisational interventions are chained one after another, a constant evolution of the generative medium is achieved.

In practice, the repeatability and cumulative improvisations enabled a gradual exploration and creation of the material for the performance. The first iterations resulted with crude and sonically unrefined musical ideas that followed the structure of dance sequences that were also in the embryonic stage at that time. During the rehearsals with dancers, the ideas evolved and all the interventions to the code accumulated resulting with the musical content that is more complex and more nuanced. The evolution continued during performances, even though the incremental changes decreased as the music and choreography converged.

5 CONCLUSION AND FUTURE WORK

With this paper we have accomplished two goals. First, we gave an overview of improvisation in its historical context and, more specifically, in the realm of live coding. By doing so, we identified common threads shared between traditional, live electronics, and computer-aided improvisation. The collected and presented previous studies show how improvisation in some form is a key part of many music genres and a fundamental element of live coding.

From there, we argued that the modalities of improvisation in live coding could be categorised into three types based on the amount and nature of pre-written code. Using a case study based on a live coding accompaniment for a contemporary choreography, we further investigated one of these modalities. In it, a musical score in the form of pre-written code gets

considerably modified during the live performances and made to follow the interaction between dancers. We also explore in detail the process of creating this piece of music and the modalities of its transformation during the performance. Within these spontaneous transformations, the influence of non-musical elements, in this case the movements of dancers, also becomes a factor. Likewise, our research shows that improvisation plays a significant part for the whole duration of the creative process, not only during its performative segments. Based on the presented case study, we argue that no artistic merit is lost when reproducing previously improvised music which has then been made “permanent” in code.

The second goal of this paper was to start a discussion and to set the stage for explorations of improvisation in live coding beyond these existing roles and modalities. This discussion should look both at the findings outlined in this paper, the historical importance of improvisation, and its state-of-the-art role in live coding. Future works might explore how tools like TidalCycles can be remade to challenge musicians and enable them to break free from patterns and habits. This could be, for example, accomplished through the use of artificial intelligence methods and adversarial systems. New tools should also be considered to shift the live coding paradigm, perhaps bringing it into the visual domain. Finally, cognitive dimensions of live coding should be researched to try and understand the relation between tools’ characteristics and the aesthetic determinism of music created in them.

The research presented in this paper shows that a deeper investigation of the role, position, and potential of improvisation in live coding is still necessary. It is our hope that by challenging the notions and understanding of improvisation and by relying on advances in human-computer interaction, new creative avenues can be discovered.

REFERENCES

Benson, Bruce Ellis.

The improvisation of musical dialogue: A phenomenology of music. Cambridge University Press, 2003.

Cascone, Kim.

Laptop music-counterfeiting aura in the age of infinite reproduction. Parachute, 2002: 52-59.

Collins, Nick, Alex McLean, Julian Rohrerhuber, and Adrian Ward.

Live coding in laptop performance. Organised sound 8, no. 3, 2003: 321-330.

Davies, Hugh.

Gentle fire: An early approach to live electronic music. Leonardo Music Journal, 2001: 53-60.

Born, Georgina, and David Hesmondhalgh, eds.

Western music and its others: Difference, representation, and appropriation in music. Univ of California Press, 2000.

Chase, Mildred Portney.

Improvisation: Music from the inside out. Berkeley, CA: Creative Arts Book Company, 1988.

Corotto, Mark.

“Mostly Other People Do The Killing: Blue.” *All About Jazz*, October 9, 2014. <https://www.allaboutjazz.com/blue-mostly-other-people-do-the-killing-hot-cup-records-review-by-mark-coroto.php>.

Feisst, Sabine M.

John Cage and improvisation: an unresolved relationship. Musical improvisation: Art, education, and society 2, no. 5, 2009.

**Freeman, Jason,
and Akito Van Troyer.**

Collaborative textual improvisation in a laptop ensemble. Computer Music Journal 35, no. 2, 2011: 8-21.

Hodgkinson, Tim.

Music and the Myth of Wholeness: Toward a New Aesthetic Paradigm. MIT Press, 2016.

**Houseman, Michael,
and Carlo Severi.**

Naven, or, the other self: a relational approach to ritual action. Brill, 1998.

**Knotts, Shelly,
and Nick Collins.**

The Politics of Laptop Ensembles: A Survey of 160 Laptop Ensembles and their Organisational Structures. In NIME, 2014: 191-194.

Magnusson, Thor.

Algorithms as scores: Coding live music. Leonardo Music Journal, 2011: 19-23.

Martin, Henry.

Charlie Parker and thematic improvisation. Scarecrow Press, 1996.

McLean, Alex, and Geraint Wiggins.

Tidal—pattern language for the live coding of music. In Proceedings of the 7th sound and music computing conference. 2010.

Nettl, Bruno.

Contemplating the concept of improvisation and its history in scholarship. Music Theory Online 19, no. 2, 2013: 1-4.

Roads, Curtis.

Microsound. MIT press, 2004.

Sansom, Matthew.

Imaging music: Abstract expressionism and free improvisation. Leonardo Music Journal, 2001: 29-34.

Van der Schyff, Dylan.

The Free Improvisation Game: Performing John Zorn's Cobra. Journal of Research in Music Performance, 2013.

**Wilson, Graeme B.,
and Raymond AR MacDonald.**

The construction of meaning within free improvising groups: A qualitative psychological investigation. Psychology of Aesthetics, Creativity, and the Arts 11, no. 2, 2017: 136.

**Hallam, Susan, Ian Cross,
and Michael Thaut, eds.**

Oxford handbook of music psychology. Oxford University Press, 2011.

Hoogerwerf, Frank W.

Cage Contra Stravinsky, or Delineating the Aleatory Aesthetic. International Review of the Aesthetics and Sociology of Music, 1976: 235-247.

Larson, Steve.

Composition versus Improvisation? Journal of Music Theory 49, no. 2, 2005: 241-275.

**MacDonald, Raymond, Graeme
Wilson, and Dorothy Miell.**

Improvisation as a creative process within contemporary music. Musical Imaginations: Multidisciplinary perspectives on creativity, performance and perception, 2012: 242-255.

Magnusson, Thor.

Improvising with the threnoscope: integrating code, hardware, GUI, network, and graphic scores. In Proceedings of the International Conference on New Interfaces for Musical Expression. Goldsmiths University of London, 2014.

Nettl, Bruno.

Thoughts on improvisation: A comparative approach. The Musical Quarterly 60, no. 1, 1974: 1-19.

Pošćić, Antonio, and Gordan Kreković.

Ecosystems of Visual Programming Languages for Music Creation: A Quantitative Study. Journal of the Audio Engineering Society 66, no. 6, 2018: 486-494.

Risset, Jean-Claude.

Fifty years of digital sound for music. In Proceedings of the 4th Sound and Music Computing Conference (SMC). 2007.

Sawyer, R. Keith.

Improvised conversations: Music, collaboration, and development. Psychology of Music 27, no. 2, 1999: 192-205.

Zattra, Laura.

The assembling of Stria by John Chowning: A philological investigation. Computer Music Journal 31, no. 3, 2007: 38-64.

**Wilson, Scott, Norah Lorway,
Roselyn Coull, Konstantinos
Vasilakos, and Tim Moyers.**

Free as in beer: Some explorations into structured improvisation using networked live-coding systems. Computer Music Journal 38, no. 1, 2014: 54-64.