Korean Electro-Acoustic Music Society's

2020 Annual Conference

PROCEEDINGS

October 30 Friday - 31 Saturday, Conference Room, Cosmos Music

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Foreword

An-Nyeong-Ha-Se-Yo?

I welcome you all to the Korean Electro-Acoustic Music Society's 2020 Annual Conference (KEAMSAC)!

This conference, hosted by Korean Electroacoustic Music Society (KEAMS), offers precious opportunities for professional composers, scholars, and any other musicians from all around the world to share characterful and noveltious issues on electro-acoustic music. As the consequence of the conference, we publish the computer music journal *Emille* every year, embracing a wide range of discussions and creative works in the field. Since 2011, *Emille* has been expanding its scope and challenging the limit by diverse international attendees to this conference. In line with the efforts and passion of KEAMS to the event, the Seoul International Computer Music Festival (SICMF) takes place together.

I would like to express my sincere gratitude to the Art Council Korea and all authors and participants for making this conference possible. Last but not least, I would like to thank all staffs and the committee members for their hard work and strong support.

October 30, 2020

Donoung Lee
President of Korean Electro-Acoustic Music Society

2020.10.30 Friday		
10:20-10:25	Kevin Parks 박케빈 Conference Chair	Opening Greengs 학회의장의 개회인사
10:30-11:30	Roger Dannenberg 로저 다넨베르그 Carnegie Mellon University	[Keynote Speech] Some Histories and Futures of Making Music with Computers 컴퓨터로 음악만들기의 어떤 역사와 미래
11:35-12:05	Michael Lukaszuk 마이클 루카스주크 University of Cincinna	Luka-chucK: a chucK-based Glitch Audio Composion Environment 루카-추크: 추크를 기반으로 한 글리치 오디오 작곡 환경
12:10-12:40	Ian Evans Guthrie 이안 에반스 거트리 Florida State University	Understanding Organized Sound and Abstract Musical Narrav es 조직화된 사운드와 추상적인 음악 서술의 이해
12:45-13:45	Lunch Break	
13:50-14:20	Hayden Patrick McGowan 헤이든 패트릭 맥고완 University of O awa	Teleology and Unity in Barry Truax's *Riverrun* 배리 트룩스의 "리버런"에 나타난 목적론과 통합성
14:25-14:55	Kiphan Janbuala 키티판 얀부알라 Seoul Naonal Univ ersity	Listen to Emojis through Significaon 음향데이터화를 통해 이모티콘을 듣다
15:00-15:30	Marko Ciciliani 마르코 시실리아니 Instut e of Electronic Music and Acouscs	Virtual 3D Environments as Composion and P erformance Spaces 작곡과 연주의 공간으로서의 3차원 가상 환경
2020.10.31 Saturday		
10:30-12:30	Jorge Sastre et al. 호르헤 사스트레 외 Universitat Politècnica de València Video: Stefano Scaran Audio: Pedro Astasio	[Workshop] Collaborav e Creaon with Soundc ool for Socially Distanced Educa@on 사회적 거리두기 교육을 위한 프로그램 Soundcool로 합동 창작하기 Be prepared with, if any, a Laptop or Smartphone, Soundcool installed. 준비물 (가능하면): 노트북이나 스마트폰, Soundcool 설치.
12:35-13:35	Lunch Break	
13:40-14:10	Nico Schüler 니코 쉴러 Texas State University	O o Laske and the Visualizaon of Electr o-Acousc Music: Laske's Visual Music Animaons 오토 라스케와 전자음향 음악의 시각화: 라스케의 시각적인 음악 애니메이션
14:15-14:45	Marc Evanstein 마크 에반스타인 University of California, Santa Barbara	Musical Moon a t Different Scales: Creav e Analysis and Resynthesis of Musical Contour Spectra 다른 규모에서의 음악적 모션 : 음악적 윤곽선 스펙트럼의 창조적인 분석과 재합성
14:50-15:20	Sepan Dwi Cah yo 셉티안 드위 카효 Indonesian Instut e of the Arts Yogyakarta	Mulmedia Analy sis in Donny Karsadi's Mulmedia Piece *I Hate My Stupid Brain* 도니 카르사디의 멀티미디어작 "내 어리석은 두뇌가 싫다"의 다중매체적 분석
15:25-15:55	Barbara Lüneburg 바르바라 뤼네부르크 Anton Bruckner Private University Linz	Vising the Virtual: P erformance Pracce in the Virtual Artworks of Rob Hamilton and Christof Ressl 가상을 방문하기: 롭 해밀톤과 크리스토프 레슬의 가상적 예술작품에서의 연주 실제

Some Histories and Futures of Making Music with Computers

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Having spent decades working in the field of Computer Music, I review some major trends of artistic and scientific development in the field with an eye to the future. While the implications of exponential computational growth are hard to predict, it seems that musical imperatives remain stable; thus, they will continue to guide us in the future. I predict a number of “futures” for Computer Music based on the persistent themes of sound creation, music representation, and music performance.

Keywords: History of computer music, Futures of making music with computers, Moonshot project.

Like computing itself, Computer Music has experienced rapid growth over sixty years or so. We have seen an evolution starting from primitive but pioneering attempts to create the first digital musical sounds and to create and control music algorithmically. Our current state-of-the-art now includes very sophisticated real-time signal processing, flexible software languages and architectures, and commercialization that reaches billions of creators and consumers. I am honored to address the KEAMS Annual Conference 2020, and I would like to take this opportunity to look both backward and forward with an aim to better understand the field and perhaps to gain some insights into future artistic opportunities and scientific directions.

Most of my work in the field has been scientific, but I feel that my work has always been guided by my experience as a performing musician and composer. My early interests in math, music and engineering led me to analog music synthesizers as well as computers in my teens. (I should add that computers around 1970 were rarely encountered outside of businesses and universities.) Through college, I learned enough electrical engineering to design and build a hybrid digital and analog synthesizer as well as a microcomputer of my own design and wired by hand, but I was pretty ignorant of emerging research. At least I was well prepared to suddenly discover a small but growing literature from authors and editors such as Max Mathews, Jim Beauchamp, John Chowning and John Strawn. I spent my years in graduate schools in more mainstream Computer Science, but on the side, I devoured everything I could find to read on Computer Music. I emerged from graduate school with a junior faculty position and a very supportive, open-minded senior faculty including Nico Habermann, Raj Reddy, Alan Newell, Herb Simon, and Dana Scott. Ever since then, I have been very fortunate to follow my passion for Computer Music making and research. I have closely followed and participated in over four decades of Computer Music development.

In this presentation, I wish to review some of my own work, which like all research is tangled in a network of other ideas and influences. From this, I hope to draw some understanding of the big ideas that drive the field forward. The occasion of a keynote address is one of those rare opportunities where one can be controversial and speculative. I will take this chance to make some predictions of where we might be going in the future. I have titled this talk in the plural: both “histories” and “futures” to hedge my bets. There are multiple ways to organize the past and multiple possibilities for the future. And speaking of the title, the phrase “with Computers” is purposefully ambiguous, regarding computers as both tools and collaborators. I will surely omit some important history and fail to anticipate much of what is yet to come, but I hope these ideas might inspire some or at least offer interesting insights.

Why Computer Music?

Anything new, any break with tradition, is going to raise questions. For some, computers and music seem a natural combination – why not? For others, as if the pursuit of Computer Music detracts from something else, what is the point? I have been collecting answers for many years, although I think there are really just a few. One idea that I was introduced to by F. Richard Moore is the *precision* that digital computation brings to music. Instead of music where every performance is unique, computers give us the possibility of precise reproduction, and thus incremental refinement of sounds with unprecedented levels of control.

Another important idea is that composers, rather than create directly, can create through computational models of composition. This has two implications. The first is that computational processes can be free of bias, so just as a tone row might help to liberate a composer from tonal habits, a computer model might create new musical structures and logic that the composer could not create directly. The second implication is that composers can inject new musical logics or languages into real-time interactive performances. This enables a new kind of improvised music where performers are empowered to bring their expressive ideas to the performance, but computers can enforce the compositional plans and intentions of the composer. It is as if the computer program becomes a *new kind of music notation*, constraining the performer in some respects, but leaving expressive opportunity in others. In my view, this is a powerful extension of aleatoric writing, which prior to computing found only limited ways to split musical decisions between the performer and composer.

These rather technical rationale for Computer Music, important as they may be to justify our work, are really just excuses for us to do what we love to do. Humans have an innate fascination with technology and automation. As soon as you tell someone that a robot is involved, the story is immediately interesting. Experiments by my advisee Gus Xia, *et al*. (2016) give evidence to what I call the "robot effect:" Suppose a human performs along with an audio recording, as in mixed music performances. How can we make the performance more engaging for the audience? One approach is using interactive, responsive, automated computer accompaniment. This in fact does not help much. Another approach is humanoid robot performers playing a fixed score, as in animatronics, but this does not help much either. However, if we *combine* computer accompaniment with humanoid robots to create *interactive robot performers*, then the audience finds the performance more engaging and more musical! This is evidence that we *are* innately attracted to the automation of human tasks, and what could be more human than making music?

All of the ideas above combine with a basic urge to explore and learn. Do we really need an excuse or rationale? Let us pursue our passion and see where that leads. After so many contributions to the arts, science, and culture, we no longer have to worry whether we are on a good path. Let us now try to characterize the path we are on and where it might lead.

The Computer Music Dream

Taken as a field, Computer Music is following a path that reflects our general understanding of music. First, *sound* is a critical attribute of music. Thus, from the very beginning, Computer Music was about making sound, combining digital signal processing with digital computation to create musical tones. One could argue the first tones were hardly musical, but through many years of research, our capacity to create musical sounds surely surpassed even the wildest dreams of early researchers.

The second critical attribute of music is organization in time, exemplified by music notation. A great deal of early research concerned musical scores, note lists, music representation and music control. Just as sound synthesis has imitated the centuries-long development of acoustic instruments, music representation and control research has imitated centuries of development of music notation, from the development of neumes in the 9th century and common practice notation, to graphic notations developed in the last 70 years or so.

Western music is assigns importance to both planning by composers and execution by performers, and thus music often has *two* characteristic representations: the score that represents instructions to performers, and live sound or recordings which convey the performance "product" to listener/consumers. (The same property holds for plays, film, and to some extent architecture and dance). Thus, a third thread of Computer Music research is an exploration and automation of performance, including interaction, expressive interpretation of scores, jazz improvisation, and performance style.

Although highly reductionist, I believe these three threads: *sound generation*, *music representation*, and *performance* serve to summarize our musical knowledge in general and also to describe the development of Computer Music.

The Impact of Technology

Throughout the history of Computer Music, the power of computers has grown at an exponential rate. It has been said that an order of magnitude difference is perceived as a *qualitative difference*, not just a numerical one, so we see a *qualitative difference* in computing every five to ten years. Each step through punched cards, time-sharing, personal computers, powerful laptops, cloud computing and mobile devices represents not just an increase in computing power but a new vista of opportunities for artists and researchers as well as a new framework within which we see problems and solutions.

Figure 1 illustrates growth in computing power over the history of Computer Music. The vertical axis is relative power, with a value of 1 assigned to the left-most year. The best measure of "computing power" is debatable, but all reasonable measures lead to the same conclusions. These graphs are purposefully plotted on a linear scale to show that, compared to today's computers in 2020, even computers from 2000 seem to have no ability whatsoever. Many believe the growth rate is slowing, so I have plotted the next 30 years with a doubling time of 3 years rather than 2, which is roughly the doubling time since 1960. The horizontal axis on the right is the same, but the vertical axis is reset to so that today's 1960's-relative computing power (2.5E+09) in the left graph appears as 1.0 in the right graph. As the graph shows, todays computers, which power Internet search, face recognition, life-like computer graphics and of course digital music processing, will seem completely insignificant by 2050. To get even a glimpse of what is in store for the next 30 years, consider that 30 years ago, software sound synthesis was barely possible. (Dannenberg & Mercer, 1992) Or consider that the release of our personal computer audio editor Audacity in 2020 was still a decade away. (Mazzoni & Dannenberg, 2002)

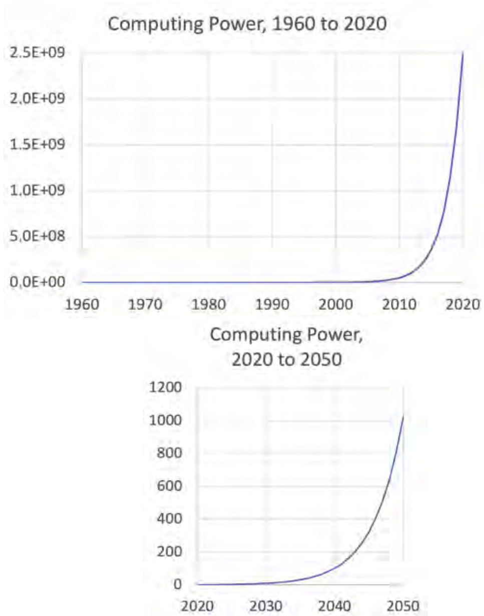

Figure 1. The growth of computing power has followed an exponential curve, doubling roughly every 2 years. Even if the doubling time slows to three years, today's computers will seem primitive within 20 or 30 years. The vertical axes represent relative power, with a value of 1 in 1960 (left) and 2020 (right).

One thing seems certain: We can imagine many developments in terms of today's technologies and devices, but the technologies of the future will be *qualitatively* different from what we have now. We will not continue to view problems in the same way. We can think about what we can do with faster computers, but it is much harder to imagine what new forms computing will take when computational power increases by orders of magnitude. We are probably better off to think in terms of musical imperatives.

A Brief History of Computer Music

To further explore these threads of sound generation, music representation, and performance, I would like to consider them in the context of some historical Computer Music developments. This is not meant to be a complete history by any means, but it will help set the context for thinking about possible futures.

Early Computer Music

In the earliest years of Computer Music, essentially all computers were mainframe computers that were programmed by submitting a stack of instructions on punched cards and receiving results in print or on magnetic tape. The first music sound generation software is exemplified by Max Mathew's Music *N* programs (Mathews M. , 1969), which already neatly capture the notions of sound and score (representation) in the "orchestra language" and the "score language." The former was designed to express digital signal processing needed to create *sound*, and the latter was a separate *music representation* language designed to express sequencing and control parameters for those signal processing operations.

Real-Time Digital Instruments

As soon as integrated circuits achieved enough power to perform basic audio signal-processing tasks in real time, digital instruments began to appear. Research systems such as the Dartmouth Digital Synthesizer (1973) and the Bell Labs Hal Alles Synthesizer (1976) led to commercial systems such as the CMI Fairlight and New England Digital Corporation Synclavier, which were soon followed by mass-produced instruments such as the Yamaha DX7 (1983). Viewed from the perspective of *performance* and the understanding of exponential growth in computer power, these developments were inevitable, even though keyboard instruments were *qualitatively* nothing like the programmed mainframe and minicomputers in use up to that time.

Interactive Systems

The combination of affordable real-time digital synthesis, the interface possibilities of MIDI, and the introduction of personal computers, all coalescing more-or-less in the 1980's, enabled a new direction in computer music: real-time musical interaction with computers. (Rowe, 1992) (Winkler, 1998) Many musicians developed interactive systems: Composed Improvisation (Eigenfeldt, 2007) by Joel Chadabe, The Sequential Drum by Max Mathews and Curtis Abbot (Mathews M. V., 1980), *Voyager* (Lewis, 2000) by George Lewis, Ron Kuivila's compositions with Formula (Anderson & Kuivila, 1990), and David Wessel's compositions with MIDI-Lisp (Wessel, Lavoie, P., Boynton, L., & Orlarey, Y., 1987) are just a few of many experimental works. In that time period, I designed the CMU MIDI Toolkit in 1984 (Dannenberg, The CMU MIDI Toolkit, 1986), inspired by Doug Collinge's *Moxie* (Collinge, 1985) language, and created *Jimmy Durante Boulevard* in a collaboration with Georges Bloch and Xavier Chabot (1989).

Interactive Systems brought compositional algorithms, previously only used for non-real-time composition, into the world of performance. Just as real-time synthesizers can be seen as joining digital sound and performance, interactive systems represent the union of music representation and composition with performance. As mentioned earlier, this created a new mode of composition. The composer specifies a piece not so much by writing notes as by writing interactions. These interactions continuously constrain and guide the sensitive musician to carry out the composer's plans. At the same time, the improviser is free to inject spontaneous and virtuosic elements that the composer might not have imagined. In the most successful work, a previously unknown and exciting synergy is achieved.

Computer Accompaniment

Another approach to interaction is based on the traditional model of chamber music where notes are determined in a score by the composer, but musicians perform the score with expressive timing. In the Computer Music world, composers were drawn to the possibilities of computation, which fixed music precisely in time, but the only way to combine that approach with live performance was to play along with a fixed recording. There was an obvious disconnect between using fixed media and the well-developed ideas of expressive performance in chamber music. In 1983, I began to experiment with algorithms, and I built a complete working accompaniment system in 1984 that could listen to my live trumpet performance, follow along in a score, and synthesize another part in real-time, synchronizing with the soloist. (Dannenberg, 1985) Similar work was introduced around the same time by Barry Vercoe. (1985) Later, my computer accompaniment work was used to create the Piano Tutor, an intelligent tutor for teaching beginning piano students (Dannenberg, et al., 1990), and computer accompaniment was commercialized in what is now SmartMusic and used by hundreds of thousands of students. Work on score following and collaborative performance is still an active topic today.

Human Computer Music Performance

Computer Accompaniment distilled the basic idea of following and score and synchronizing performance, but in music, there are many more problems related to collaboration. This came to my attention around 2005 when I was playing in a rock band's horn section. As the only trumpet, and not a strong lead player, I began to think how much better it would be if I were the *second* trumpet alongside a great high-note player. It did not take long to imagine I could use my computer accompaniment techniques to create a virtual musician for the band. However, I soon realized that the band did not always follow a score strictly from beginning to end. Also, horns do not play all the time, so how would the virtual player enter precisely in time and in tempo without following a leader? A virtual player might "listen" to the keyboard player, but the keyboardist improvises chord voicings and rhythms, so there is no detailed score to follow there.

These and other problems led me to think about musical collaboration much more broadly than before. Synchronization is achieved not only by following scores, but by following the beat, following chord progressions, visual cues, following conductors, becoming the leader, and combinations of these things. Parts are specified by traditional scores, lead sheets, drumming or percussion styles, and analogy ("I want you to play this part the way Bill Evans might do it.") In other words, the broader goal is not simply an "adaptive sequencer" that synchronizes to a pre-determined stream of notes, but an *artificially intelligent musical partner*.

We can see related work in laptop orchestras, networked music performance, and artificial intelligence for composition. These are all approaches that use technology for human-human and human-computer *music collaboration*.

Interlude

Let us try to sum up some ideas of this brief discussion. Computer Music has ridden a wave of exponential growth in computing power to get us where we are today. Much of our progress could never happen without integrated circuits, powerful computers and the whole information age (for example, only the pervasive adoption of computing in daily life could drive down price of billion-transistor processors to affordable levels.) However, the main directions of Computer Music can be seen as an attempt to reproduce and then extend traditional music concerns in three areas: sound, music representation, and performance.

We have discussed an historical progression in which researchers explored the production of sound, music representation and control, real-time interaction, computer accompaniment, and collaboration in general. The future will bring unimaginable computing technologies and with it multiple qualitative changes in the way we think about or experience computing. However, our principle musical concerns are likely to be the same ones we have pursued for centuries if not millennia, so with that assumption let us consider some implications for the future.

The Future of (Computer) Music

One way to conceptualize the whole of musical concerns is illustrated in Figure 2. Here we see "Instruments" as the world of sound generation and processing. While instruments produce sounds, musicians organize sounds into phrases, and there is much work to be done to understand phrases (more on this below). Phrases (or, in some terminologies, "musical gestures") are assembled to form compositions. Compositions are performed, giving rise to many concerns of collaboration and coordination. Let us consider each of these realms separately.

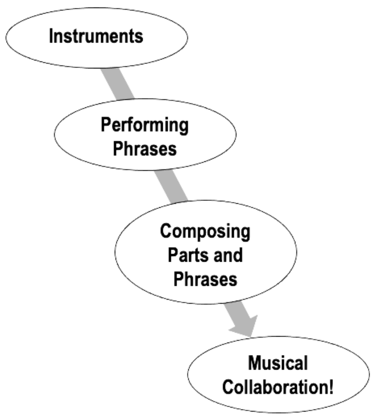

Figure 2. Schematic of Computer Music areas of concern.

Instruments

Even after decades of research, instrument modeling remains elusive. The non-linear, 3-dimensional physics of acoustic instruments are complex (Bilbao, 2009), and our perceptual abilities are exceptionally refined, making even slight imperfections quite apparent. Musicians take many years to learn to control acoustic instruments, and without control, even real acoustic instruments do not make interesting musical tones. It seems that in the future, orders of magnitude more computation will be applied to acoustic instrument simulation as well as to machine learning to discover how to control them to produce musical results. From there, new possibilities will emerge to artistically manipulate "physics" in our simulations to design new instruments and new sounds, informed but not limited by real acoustics. Spectral synthesis models based on computational models of perception are also a promising direction for new sound creation.

Another interesting direction is physical robotic instruments such as those explored by Trimpin, Eric Singer, Ajay Kapur and others. I helped Ben Brown and Garth Zeglin construct a high-performance robot bagpipe player, McBlare, at Carnegie Mellon University. (See Figure 3.) The "robot effect" described earlier suggests that we should pay attention to robots, and just as musicians have been able to use computers and sensors developed for other applications, I expect humanoid robots created with other purposes in mind will offer very engaging modes of musical performance.

Figure 3. McBlare, Carnegie Mellon's robotic bagpipe player.

Phrases

Many years ago, the mantra "sampling is dead" was frequently heard among computer music researchers. The basic idea of samples is to record "notes" of instruments and play them back on demand. If a violin plays a range of 4 octaves at 10 different dynamic levels, that is about 500 sounds, assuming we can find reasonable ways to control duration and simulate vibrato. In the early days of limited memory, even 50 very short samples that required "looping" to extend them was already expensive, so it seemed hopeless to achieve high quality through sampling. Over time, however, memory prices came down, so sample libraries could add longer samples and many variations of articulation, bow position, and even extended techniques. It seems that our predictions were premature.

However, expressive continuous control is still a problem for samples, and here is where *phrases* enter the picture. My work in the 90's showed that the details of individual notes are highly dependent upon context. (A Study of Trumpet Envelopes, 1998) For example, a slurred transition between two trumpet notes is entirely different from an articulation where the air is briefly stopped by the tongue, and details of the transitions are also affected by the pitches of the notes. Thus, *phrases* are critical units for musical expression and even timbre, yet they have been largely ignored.

In the future, either sampling will have to "die" or expressive phrases available to string and wind players will disappear from electronic music. Well, at least we will have to solve the problem of sample selection from ever-growing libraries that now reach gigabytes, and we will have to do something about the rigidity of recorded samples once they are selected. There is certainly room for more research here. As storage limits disappear, the real limits of sampling are becoming apparent, and old solutions such as work from my lab on Spectral Interpolation Synthesis (Combining Instrument and Performance Models for High-Quality Music Synthesis, 1998) and other work on physical models are re-emerging.

Composing in the Future

Recently, there has been a resurgence of work on automated computer music composition. Every innovation in Artificial intelligence – rule-based expert systems, constraint systems, production systems, Bayesian approaches, neural networks and now various kinds of deep learning – has been applied to model the compositional process. We can expect this trend to continue.

In my view, recent work, while technically impressive, has been musically disappointing. Perhaps the success of deep networks in other areas has misled researchers into putting too much faith in data-driven learning methods. Composition is regarded by many as a problem of imitation: Train a machine learning algorithm with examples of music and try to generate something similar. But how many composers aim to (merely) imitate? Composers have not played a large role in recent research, and in many ways, earlier research by composers produced more musical results. Composers have a better understanding of what composition is really about, and it seems that deep learning is no substitute (yet) for human understanding. Then again, with another 10 years' growth in computational power and the qualitative changes it will bring, maybe time will show that I am just taking a short-sighted view.

There is clearly room for more research here, and in the long run, we will see a slow and steady progression beginning with simpler tasks such as making drum loops, harmonization and creating musical textures. From there, perhaps we will develop composition systems that work with in highly constrained settings: improvising over a set meter and chord progression, composing percussion tracks or bass lines given a set of parts, or generating call-and-response melodic units. Eventually, we will come to understand higher-level structures, music anticipation and surprise, and music design to the point we begin to see truly original musical creations by computer.

Performance in the Future

Live performance with computers is still nascent. There are some stunning pieces in the repertoire, and plenty of techniques from composed improvisation to computer accompaniment, but let us be honest and critical here. Interactive systems are largely based on triggers to step through fixed sequences, simple responses to simple input patterns, or just random but interesting choices. Machines have little understanding of tempo, timbre, form, anticipation or surprise, and it is as much a stretch to call computers true collaborators in 2020 as it would be to call the pianoforte a musical collaborator in 1750.

Computer accompaniment systems coordinate with musicians at a finer time scale by tracking performances note-by-note. Work with Gus Xia shows that deeper musical understanding can dramatically improve prediction in collaborative performance. (Xia, Wang, Dannenberg, & Gordon, 2015) So far, computer accompaniment systems are quite shallow and fail to adapt as collaborators might. These systems are also brittle, typically applying only one method of listening or processing input, whereas musicians have a much richer repertoire of techniques including score analysis, phrase analysis, entrainment to beats, leading and following, giving and accepting visual cues, source separation, and exceptional musical awareness.

One of my research directions is to enable human-computer collaboration in the performance of beat-based music, an area largely ignored by Computer Music research. It is not clear who would actually perform with such systems, but it is an interesting challenge. In any case, we have a long way to go to develop more computational music understanding for live collaborative music performance.

A "Moonshot Project" for Computer Music

My colleague Rowland Chen created an interesting challenge that I believe exemplifies the current problems in Computer Music research. (Chen, Dannenberg, Raj, & Singh, 2020) Just as the goal of putting a man on the moon stimulated an array of technical advances in space exploration, with wide-ranging and important spin-offs, I believe a good "Moonshot" project might stimulate and stretch Computer Music research.

Jerry Garcia was a founding member of the Grateful Dead. He is dead, but millions of fans miss him, and thousands of hours of live recordings survive. What if we could create a faithful imitation of Jerry Garcia? The problems we would have to solve span the range of Computer Music concerns, including:

- Sound: Model Garcia's electric guitar sounds, including effects, amplifier distortion and sound propagation. Vocal sounds seem even more difficult.
- Control: Isolated guitar sounds are not enough. Perceived sound is influenced by articulation, bends, vibrato, frets and fingerings, all of which are time-varying, constrained by physics, the neuro-musculature system and mutual dependencies. Again, the singing voice is yet more difficult.
- Composition: The Grateful Dead are known for long improvisations and launching the "jam band" movement. One would expect a "Jerry Gracia" model to create new improvisations with long-term coherence, interaction and collaboration with human bandmates and faithful adherence to style. (Perhaps a continuing evolution of style is also necessary to keep fans interested and to justify new performances.)
- Collaboration: Part of the essence of the Grateful Dead is the collaboration among the band members in constructing extended "jams." Musical coordination exists at all levels from beat- and measure-level synchronization to larger sections and transitions.
- In order to accomplish all this, it seems necessary to greatly extend the state-of-the-art in machine listening, especially source separation techniques. If we could isolate instruments in the 10,000 hours of Grateful Dead concert recordings that are available for study, we would at least have a wealth of interesting data. Even with that data, we need advances in the analysis of structure and style in those performances.

Whether we actually embark on a "moonshot" project, it is a good practice to set goals and to dream big. In my experience, real objective musical goals are invaluable in setting the research agenda.

Conclusions

If we stand back far enough, we can see Computer Music as a grand undertaking to understand and automate *every* aspect of music making, with a clear progression:

- From primitive sound generation and reproduction, we have learned to create new sounds. Research continues to explore new sounds as well as to create better models for known acoustic sounds in all their richness and complexity.
- Beginning with simple event lists and other score-like representations, we have developed more complex and dynamic control approaches, leading to imitative computer-generated compositions and to interactive, responsive music systems.
- From early performances with fixed media, we have developed computer accompaniment systems, responsive robot musicians, and we have begun to study collaborative music making in greater generality.

I believe these trends help us to anticipate what the future will bring: Richer sounds and better synthesis models, better understanding for building higher-level musical forms from phrases to entire music compositions, and more sophisticated approaches to collaborative music making between humans and machines.

While these themes seem to be predictable, the exponential growth of computing power makes the details hard to even imagine, and we should expect *qualitative* changes on par with the shift from mainframes to laptops or books to Internet. These changes will continue to surprise us, but they will also open new and interesting avenues to pursue our goals.

Ultimately, our attraction to modeling, automation and computation in music is driven by the natural human urge to explore and learn. Let us hope that through this experience of constructing knowledge, we also learn to use it wisely for the benefit and enjoyment of society.

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Carnegie Mellon University and my many stellar colleagues and students, from whom I have learned so much. Throughout this paper, I have referenced particular papers I had in mind, but I also mention areas full of great contributions by many additional researchers. I believe a quick Internet search with obvious keywords will lead you to their papers, and I hope dozens of authors will forgive me for omitting references to their work here. I have certainly learned a lot from my Computer Music colleagues, whose friendship over the years continues to make this a great journey.

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Luka-chucK: a chucK-based Glitch Audio Composition Environment

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The Luka-chucK is a glitch audio composition environment that uses the chucK programming language as its audio engine. It can be used to generate audio fragments or entire works. A user interface is provided using communication to Max/MSP via open sound control. A key motivation for this project is the development of features that allow the user to anticipate and control sonic results that emerge from digital audio glitches, and to increase the compatibility of such sounds with other materials used to compose electroacoustic music. With the interface, users can input data to modify pitch, rhythmic, timbral and textural elements by affecting algorithmic devices such as looping and conditional statements. The glitch sounds can also be modified by conventional tools such as a step sequencer, musical keyboard and the use of low frequency oscillators. The environment includes a number of audio instruments based on techniques such as foldover from aliasing, the use of infrasonic frequency content, and quality factor glitches with resonant filters. The purpose of this paper is to discuss motivations, applications and further work related to the Luka-chucK project.

Keywords: glitch, failure, ChucK, computer music programming

The use of audio glitches to produce new sound works raises questions about the relationship between the idea of "failure" and the artist's own creative intentions. While some practitioners value sharing control with the machine itself to produce complex results that go beyond their own expectations (Menkman, 2010), others seek to domesticate glitch sounds so that they can be controlled within other pitch/timbral/rhythmic constructs that belong to the artist's compositional methodology.

The tools that I have created for this project sacrifice a certain amount of wildness for this very reason. In my own fixed-media work, for example, there is often a juxtaposition of sound synthesis, environmental recordings and MIDI instrument samples. The sound material that forms the composition covers a wide spectrum of noise, environmental and conventionally musical sounds. For this reason, one of the goals of this project is to investigate how the parameters of digital audio glitches can become compatible with other materials and integrated into the design of a sound work instead of placed as a kind of referential noise object. Luka-chucK consists of eight instruments for glitch audio that are able to act freely or as an interactive community of players. The environment can affect global changes and fuel greater interaction between instrument components.

This article discusses the way that glitch aesthetics influenced the development of the project, system design and use of the chucK language, provides technical information on the available glitch audio software instruments, and describes possible musical applications using the Max/MSP interface.

Tapestries of Sound

Writings and original works that use glitch sounds can make the use of malfunction feel subversive. Texts such as Caleb Kelly's *Cracked Media* position glitch as part of a trajectory stemming from earlier explorations of nonmusical sound such as the rise of instrumental extended techniques and the works of artists such as Luigi Russolo. For Kelly, digital glitches help establish the "noisy project of twentieth century experimental music" (Kelly, 2009). In *The Aesthetics of Failure*, Kim Cascone emphasizes that glitch sounds can work within a wider expressive range, producing both horrible noise and "wondrous tapestries of sound" (Cascone, 2000).

A project that seeks to control glitch sounds may conflict with the historical relationship between failure and indeterminacy, but at the same time makes these sounds available to practitioners outside of experimental electronic music who work with more defined ideas about duration and frequency. For the purposes of this project, a digital audio glitch can be understood as a sound that results in the computer's failure to represent the intended or expected sonic result of a signal, instrument or technique.

General Design and the use of ChucK

The Luka-chucK environment exists in a fuzzy space between program, system and instrument or meta-instrument. The design was influenced by other projects that use the capabilities of a particular computer music software or language to create a platform for exploring a specific set of techniques. Examples include Kazuaki Shiota's Max/MSP-based *TranSpell* system for composing based on overtone extraction (Shiota, 2007), and the SuperCollider-based SuperSampler for computer-assisted improvisation (Wu, 2017). I refer to the set of tools as an environment because of the way that more global conditions can be imposed on the behaviour of instruments.

This environment is mostly reliant on ChucK for generating audio and controlling time. Max/MSP was used because it offers a far greater collection of objects for designing a user interface than available in the MAUI API for Chuck's miniAudicle IDE. Many of the instruments in the Luka-chucK are based on the exploitation of thresholds, in particular the acceptable input for methods belonging to UGens in ChucK. Such misuse often results in relative, not absolute control over time. The flexible approach for asserting control over time in ChucK revolves around the ability to forward time using the "now" keyword. Framing events around "now" makes the language well-suited for dealing with unpredictable sounds that result in an ambiguous relationship between duration and frequency parameters. For example, in Figure 1., the use of an infrasonic frequency argument and lower than expected .bodySize can make delays used in the Mandolin UGen more audible.

The majority of the audio glitches in this environment rely on synthesis-based ChucK UGens. The use of recorded sounds was avoided as the complex harmonic spectra of acoustic sound sources might obstruct the ability to control the resultant glitches. Oscillators and impulses proved easier for testing.

```
[0.00001,0.001,0.05,0.1] @=> float lowSizeArr[];

fun void notMandoInit()

{
   for (0 => int b; b < notMando.cap()-1; b++)
   {

    mandoGain => mando.gain;

    5 => notMando[b].freq; |
    lowSizeArr[b] => notMando[b].bodySize;

    0.9 => notMando.pluck;
    0.3 => notMando.stringDetune;
```

Figure 1. Some default settings for the *notMando* instrument

Each glitch instrument uses the language's chubgraph class to develop new objects that can be used with the same level of autonomy as any UGen that is native to the language. Chubgraphs are reconfigurations of existing UGens and do not introduce any new synthesis or processing capabilities to the language. Including DSP glitches complicates the chubgraph as the instruments of the Luka-chucK reveal new possibilities that are not included in the C++ code for each UGen.

```
UGen ensemble[7][7];

for (0 => int v; v < 7; v++;)
{
  resonGlitch rezGlitch[v] => ensemble[v][v];
  foldPitch foldPches[v] => ensemble[v][v];
  clickHarm clickCloud[v] => ensemble[v][v];
  notBLit noSaw[v] => ensemble[v][v];
  microPan notPan[v] => ensemble[v][v];
  notMando notMand[v] => ensemble[v][v];
  notWG noWG[v] => ensemble[v][v];
  notBowed noBow[v] => ensemble[v][v];
}

fun void mapping1(int inst1, int inst2,int member, int affected)
{
    while (true)
    {
      ensemble[inst1][member].last() => ensemble[inst2][affected].gain;
      100::samp => now;
    }
}
```

Figure 2. Graph demo of system design

The code above shows how instruments can interact within the environment. Passing each instrument into an ensemble array increases the possibility for interaction between instruments. A set of mapping functions are used to share the .last() (last sample amplitude) and .freq (for UGens with this method) between instruments. The Event class is used for sharing more asynchronous data between instruments such as noteOn messages.

Overview of Glitch Instruments

This environment consists of eight glitch instruments. The guiding principle in the creation of each one is the exploitation of a threshold. Some play with thresholds based on digital audio theory such as the Nyquist frequency. Others play with thresholds set for input to UGen methods. Others play with perceptual thresholds (i.e. the expectations for the sound of a physical model).

Instrument Name	Source of Malfunction
resonGlitch	filter Q, infrasonic Hz
foldPitch	aliasing, ultrasonic Hz
clickHarm	impulsive noise
notBLit	aliasing, ultrasonicHz
microPan	impulsive noise
notMando	Manipulation of bodySize
notWG	Manipulation of pluck
notBowed	Manipulation of vibratoFreq

Table 1. List of Instruments with main sources of malfunction

1. *resonGlitch*

The resonGlitch was my first encounter with digital audio malfunction in chucK. The module is based on the routing of an oscillator (sine, triangle or pulse wave) through a resonant bandpass filter. The main cause of the malfunction is the use of a value less than 1 for the Q (quality factor) method of the ResonZ UGen. When active, the wave is audibly distorted from the original sine shape and its frequency bends fluidly with little predictability.

In terms of controlling the glitch sound, the use of infrasonic frequencies for the oscillator controls the duration of each chirping sound within the frame of the value passed to the "now" keyword in chucK. In this case "now" is acting as a kind of refresh button, controlling time on a larger scale, where the value of SinOsc controls the duration of rhythmic units within the time frame of "now." Specific frequencies cannot be controlled but more general pitch contours can be heard with the use of the ResonZ .freq method. The frequency of the oscillator can also be assigned as a quarter, eighth, etc. duration according to the public tempo clock class in the environment.

The Q being less than 1 is integral, and the closer the Q is to zero works much like it would with the conventional application of a resonant bandpass filter, adding an amplified sense of resonance. The actual frequency of the glitch sound does not follow the value passed to the resonant bandpass filter but this argument can be used to transpose the sound up or down in a more general way. The effect becomes audible above approximately 5000Hz.

```
function void filterGlitch(int chirpDurHi, int churpDurLo, float inQ)
  {

      Math.random2(chirpDurHi,chirpDurLo) => s.freq;
      Math.random2(8000,10000) => rez.freq;
      inQ => rez.Q; // default Q

function void amp(float ugenGain) //
  {
   (ugenGain * 10) * 0.0000000000001 => gain1.gain;

  }
}
```

Figure 3. resonGlitch requires very low gain to be audible (not harmful) and not distorted from clipping

2. *foldPitch*

The use of foldover resulting from aliasing is a common glitch audio technique. Computer musicians such as James Dashow have experimented with the control of foldover to form pitch hierarchies through the organization of these sounds into triads (Dashow, 1978). This instrument does not introduce any new ideas about the production of foldover itself but does have some built-in functions for controlling pitch content with a high degree of specificity. In addition to specifying pitch classes using linear octave or MIDI note values, strings for triads and seventh chords, polychords and clusters are available within *foldPitch*. The use of varied pitch converters with the *foldPitch* was inspired by the MIDI processing in the DAW LMMS (Linux Multimedia Studio), which tries to emulate this broad inclusion of pitch collections in and outside of standard tonal/modal music approach.

```
for (0 => int f; f < foldME.cap()-1; f++)
{
    1 => foldPitch[0].randOsc;
    2 => foldPitch[0].wave;
    "7th chord" => foldPitch[0].mode;
    "Gm7" => foldPitch[0].freq;
    "A5" => foldPitch[4].freq;

    tempo.quarter => now;
}
```

Figure 4. Accessing Pitch Collections in *foldPitch*

In Figure 4, an array of PulseOsc UGens (selected using the .wave method) are used. When the .mode method is given a triad of seventh chord it assigns the .freq of the specified array member along with the next 2-3 members, to form the chord. This particular chubgraph was used in my 2015 piece *My Metal Bird Can Sing*, in which it was juxtaposed against pitches played into the Logic Pro synthesizer Sculpture using a MIDI keyboard.

3. *clickHarmonizer*

This instrument is based on the click heard from impulsive noise, the signal discontinuity created when the frequency argument of a filter is changed instantaneously. The amplitude of the clicks is greater than that of the filtered SinOsc. This difference is exploited using a noise gate to "harmonize" the artifacts, applying pitch shifting and/or a comb filter to signal above a threshold. The glitches are controlled by imposing pitch relationships through the comb filter delay time and the degree of pitch shifting. The instrument is meant to produce a crackly cloud-like texture but can be used for well- defined gestures.

4. *notBLit*

The BLsw is based on the band limited sawtooth wave oscillator from the Synthesis Toolkit (Cook and Scavone, 1995) that is included as a UGen in ChucK. Where malfunction from misuse occurs is in the relationship between the .harmonics (harmonics in the passband) and the.freq arguments. Using values above the sampling rate for the harmonics function causes the UGen to sound like a mix of quasi-synchronous impulses (the length of the train depends on the time passed to "now"), along with some foldover. The instrument can be controlled with .freq arguments of less than 200Hz in which different streams and rhythmic grooves are produced. In the 1-

100Hz creates predictable streams of impulses rates but the grooves produced by the 100-199Hz range do not possess an audible relationship between time and frequency. Arrays could be used to store frequencies that produce similar sounds in the 100-199Hz range but this feature does not exist at present.

5. *microPan*

Recent computer music tools have begun to explore microsound in domains outside of traditional granular synthesis, such as spectral processing. This instrument uses signal discontinuities created by randomizing the Pan2 UGen at a rate below 100ms. The signal after the randomized panning is sent to a pitch shifter so that it is more audible compared to the Pan2 input (an oscillator UGen). The oscillator is present because Pan2 needs a signal to malfunction and does not create glitches alone. Its frequency can be infrasonic, ultrasonic or within a normal range. The pitch shifting is what controls the contour of the sound. Exact frequencies of the glitch sounds produced by this instrument can be understood using a function within the chubgraph for pitch detection based on the PitchTrack class from the set of new UGens from CCRMA chugins page on GitHub. In granular synthesis the single grain itself is trivial compared to the manner in which larger groups are layered (Truax, 1988). With the *microPan* instrument the computer musician also has to think about sculpting larger textures and timbres through manipulations of microsonic durations and inter-grain delays.

6. *notMando*

The final three instruments in the environment use chucK UGens based on physical models from the STK. The use of these models within the environment is not about improving them by adding envelopes, filters, delays or convolution to create more effective realizations of the instrument (Kapur et al., 2015). It is focused on investigating how parameters that relate to articulation and timbre can be used to drive pitch or duration.

The *notMando* instrument extends the mandolin model from the STK. The bodySize method should take a float between 0.1 and 1.0 to change the timbre of the violin based on a perceived larger or smaller mandolin. The use of particularly small floating point values for bodySize can create audible echoing effects. Coupled with low (but still audible) frequencies around the 40-70Hz range also adds distortion.

7. *notWG*

This instrument repurposes the BandedWG Ugen that models struck and bowed percussion instruments such as the Tibetan bowl. The pluck and bowPressure methods of this model are typically adjusted for a more realistic performance, but in the case of this instrument the parameters are modulated using an LFO. An audible sweep of artifacts follows the shape of the LFO curve and when given a frequency above 20Hz, the oscillator can be used to provide pitched material from modulating the parameters. The instrument works well with infrasonic frequency arguments passed to the freq parameter of the BandedWG Ugen. This adds another level of pitch control but does not follow a predictable pattern. For example, a frequency of 15Hz will sound higher than 16Hz.

8. *notBowed*

This instrument uses the bowed string model from the STK. This chubgraph repurposes the vibrato and vibrato gain functions of the original UGen. When the vibrato frequency is used approximately between 50-100Hz, it begins to produce pulsating grooves with speeds that can be controlled using the vibrato gain level. As is the case with *notBLit*, this instrument offers more relative than definite control of parameters. Pairs of vibratoFreq and vibratoGain values could be stored in arrays for later use.

Communication with Max/MSP

While the components of this environment can be used solely with text in chucK, the use of a user interface designed in Max/MSP is the place where this project becomes less a set of instruments and more of an environment for creating new sound works. This component features large-scale conditions such as the use of a LFO's and an ADSR envelope to manipulate the overall output gain, a slider that can condense the general width of certain random number generators in chucK, and the ability to record audio output into buffers, playback, mix and write to files.

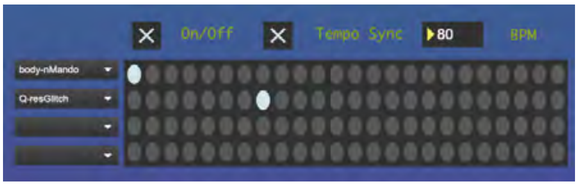

Figure 5. Sequencer using Max

The step sequencer offers grid-based maniplutation of parameters belonging to each instrument, with independent event streams of up to four parameters at a time. For example, the quality factor of the *resonGlitch* and the bodySize of *notMando* can rely on the same pattern or take on individual streams. If this component is on, values move across the matrix, activated once selected from umenu objects.

A subpatcher called “routingParams” allows for the mapping of parameters across certain instruments. For example, the chord specified for *foldPitch* can be mapped to the pitch array used for *notMando*. The use of OSC messaging allows UI to affect the set of mapping functions (see Figure 2.). At present the mapping is limited in terms of the degree to which parameters can be exchanged. For example, the STK UGens share certain methods (e.g. noteOn) that are not present in the oscillator UGens. The majority of UGens have .freq, .gain and .last methods that can be useful in this context. Mappings should be chosen carefully to avoid interfering with the sequencer.

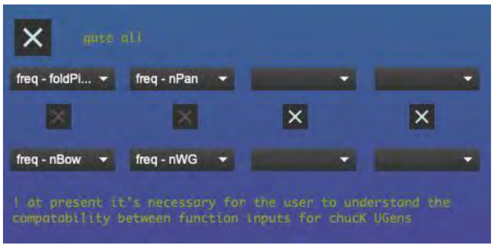

Figure 6. Routing parameters to create interdependency between instruments

The environment also allows the user to reconfigure some algorithmic processes within the chucK code using number boxes and dials. For example, the user can trigger timed events specified using a for loop, specifying the number of iterations, time passed to “now” in chucK and mapping of the loop control variable. At present the best results for creating sound with this environment come from combined use of the Max/MSP UI and the chucK code.

Conclusion and Future Work

By exploiting digital audio thresholds and repurposing the function methods of UGens in the chucK language the instruments in the Luka-chucK environment provide the user with a wide expressive palette based on sounds that are not readily available using other common synthesis and processing techniques. The use of digital audio failure in this environment is not focused on the glitch as a catastrophe that must be distinct from the regular function of the system (Betancourt, 2016), but seeks to investigate the expressive potential for glitches outside of their designation as noise sounds.

Future work includes the incorporation of MIR features such as the use of real time quantization between events, concatenative sampler synthesizer to increase the compatibility between the sounds produced by the environment and by other electronic music elements within ChucK, or even live sampling of acoustic instruments.

The reduction of audio glitches to pitch/timbral and rhythmic constructs that I have used in my own compositional output often deal with scales, modes, chords and temporal units mostly found in tonal/modal music. An important addition to this project would be the ability to map these sounds to structural elements that are common to music within other cultural spheres. There is already important work being done in exploring the compatibility between computer music and nonwestern traditions. For example, the Virtual Gamelan Graz projects features event scheduling that allows for gradual transitions that are idiomatic when performing gamelan music (Grupe, 2008). Such features would help extend the environment beyond my own creative practice and hopefully provide a meaningful resource for other artists.

Documentation and examples can be found at https://www.michaellukaszuk.com/music-tech.

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Understanding Organized Sound and Abstract Musical Narratives

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Although music with indeterminate pitches is arguably as old as historic music itself, it has become an increasingly popular goal of composers ever since Varèse's *Ionisation* and other "soundscapes." However, by in large composers today who write for acoustic instruments take advantage of their innate pitches, which provide a tonal framework for listeners. This is not so with electronic music, where synthetic sound is much more easily achievable, and where serial procedures and/or rhythmic complexity obscure any clear pitches from creating a tonal spectrum. For the average listener—and even many acoustic composers—these "organized sounds" pose a challenge: How does one interpret music with no clear tonal teleology, but only unfamiliar sounds? A graphic scores cannot reveal what an individual may be *feeling*, for anything *sounding* eccentric one cannot *feel* the form. There needs to be an approach that both reflects this sonic reality but also allows for personal interpretation when there is no traditional teleological path. While the answer may lie in Stockhausen's "moment form" and its variants, there is still a philosophical issue with the concept. While the mind does not think entirely linearly, it does ultimately follow a narrative. To follow a non-linear non-narrative would be distracting and impossible; to follow a non-linear narrative would not be. It is partly a matter of awareness: Once a listener realizes that they are listening to a narrative, they no longer need to comprehend the sounds any more than they need to understand a *de stijl* painting. Not all music has a perceivable form, but all music speaks: and what is spoken is its narrative. The concept of a "narrative form" also aids composers uncomfortable with nontonal soundscapes by providing a freedom that is enhanced through loose guidelines. Esoteric sound rarely remains so once a composer turns those noises into characters. Sound need not be linear or immediately apparent, but it always has a story.

Keywords: electroacoustic music, theory, analysis, cognition, form, aesthetics, interdisciplinary art, moment form

Composers today want to be innovative, relevant, and most of all, *respected*. They want to do what no one else has done, routing listeners on new paths to discover surprising timbres. However, the many similarities of "international popular music" with diatonic harmonies and regular grooves has become the favored brand of the populace in most (if not all) first-world countries and many second-world ones. Composers' routes have become distracting, and their surprises confusing—the question is not if, but *why*. This paper builds on the author's previous research presented in *Rhythm as Function*,[1] but instead of focusing on cognition, the author will (1) highlight philosophical incongruencies pertaining to postmodernist thought in respect to the use of a musical canon (especially one featuring the Common Practice Period) in pedagogy and history, (2) a similar critique against the term "atonality" and its implications, (3) provide a critique on the rejection of form in favor of chance, (4) highlight the important relationships between visual and sonic arts, (5) suggest extramusical tools that can make phenomenological listening experiences seem less random, and (6) recommend a more aesthetic-oriented approach to musical analysis, especially for genres where pitch, harmony, and rhythm are superceded by timbre and texture (hereby called "abstract music" for sake of simplicity, though not meant in a derogatory manner). Such abstract music will not necessarily become more accessible, but at the very least, analysts and composers may hopefully be more aware of how their modes of communication with the audience will influence the reception and interpretation of their works.

I

While the goal of this essay is ultimately to provide analytical and compositional resources to aid in the communication of otherwise abstract musical pieces in nontonal music, the author will first overview the misconceptions on the aesthetic and philosophical dilemmas posed by postmodern music. We can see this in heated debates today, such as in the United States' Society of Music Theory, where many scholars are seeking to abolish the Common Practice Period canon on grounds that it is irrelevant, racist, and historically misguided. Whether this is true or not, their canon is not entirely arbitrary, considering that music programs and genres around the world draw on the handful of so-called "Classical Composers" to develop their modernist ideologies. (There do exist some cultures and subcultures that are untouched by this canon, but it still has single-handedly exerted more influence on today's popular musics than any other world genre.) More importantly, without a canon, we cannot find from where many others genres began, and neither can we decipher the roots of what the populace desires. It would be like trying to understand postmodernism while eliminating World History before 1900 from curricula: without the backdrop, we do not know from where we came nor to where we will go. This is especially important in cognition, prenatal and postnatal development, and multicultural aesthetical similarities, which are all pertinent to the topic at hand.

A similar argument posited against retaining a canon is the same claim advanced by some Enlightenment empricists called the "Blank Slate Controversy," insisting that humans are born with no knowledge, and thus their reality is entirely shaped by their experience. This is not entirely true, although some experiences *are* shaped by external stimuli that can only be experienced postnatally.[2] These postnatal experiences may—and likely do—include the arts to some degree, since they are experienced outside of the mother's body during the pregnancy. However, every culture's musical history has an element of order and freedom, so that neither total control nor total chaos seem to have existed in earlier ages, and will probably cease to exist in popular musics in the future. Yet the avant-garde—especially artistic genres emerging at the turn of the twentieth century—has continually been rejected by the majority of people in every culture since its inception, having an "unfamiliar syntax… extremely complex syntax… [or] no syntax." Thus, for over a century, musical innovation has advanced through pluralism, not a steady progression.[3]

To this point, Joaquim M. Beitez, himself expounding Leonard B. Meyer, notes that music ceased to progress in the twentieth century and became static and pluralistic. "Popular," vulgar, accessible music favored the sound of the "Content" (for example, Neoromanticism or Soviet Realism); integral serialism praised immaculate construction or "Formalism" (for example, Babbitt and Boulez); and avant-garde eclecticism favored the plethora of "Materials," which Meyer euphoniously calls *transcendentalism* (for example, Berio's Sequenzas).[4] What is interesting about Stockhausen and his "moment form"[5] seemingly attempted to unify the "formalist" and "transcendental" aesthetics; similarly, Berio's in his eclecticism of collage, humor, pastiche, and ultramodernism attempted to combine "content" and "materials." Yet to the average listener—and a great many of anti-academic composers today—Stockhausen (or Babbitt or Boulez) sounds anything but formally coherent, and Berio tends to seem formally lax. Yet non-musical elements of Berio's music—namely title, narrative, and visual art—make his style more approachable for the average person than Stockhausen. Clearly, so-dubbed "atonal music" is vindicated on many grounds, not simply tonality or even strictly musicality.

II

Indeed, atonal music for its own sake is considered ultramodernist and inaccessible by the populace, and yet this is largely due to elements other than pitch. As noted in *Rhythm as Function*,[6] rhythmic cells, meter, and above all, tempo can provide direction in music, even in music where no tonal center can be perceived. Yet while music with indeterminate pitches is arguably the earliest form of music in human experience (take for example the prevailing prehistoric narrative of Aboriginal music), eradicating discernible pitch has become an increasingly popular goal of composers ever since Varèse's *Ionisation* and other "soundscapes." However, by in large composers today who write for acoustic instruments take advantage of their innate pitches, which provide unintentional yet inevitable tonal implications for listeners.

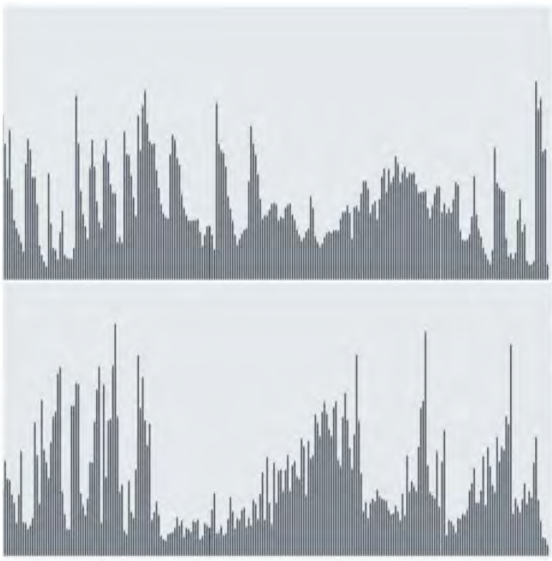
This is not so with electronic music, where synthetic sound is much more easily achievable, and where serial procedures and/or rhythmic complexity obscure any clear pitches from creating a tonal spectrum or natural harmonic series. Furthermore, technology provides the opportunity to create unnatural sounds, sounds that are not only new in combination, but new in and of themselves. Almost anything is possible formally and sonically, without any references *a priori* to interfere with the listener. Compositional continuity is only bound by the imagination of the composer, and "organized sound" becomes infinitely new and novel sounds continue to be explored and shared.

For the average listener—and even many acoustic composers—these "organized sounds" sound *dis*organized irrespective of tonality, and pose a challenge: How does one interpret music with no clear teleology through tonality or form, but only unfamiliar sounds? How should one analyze the structure and form of such complex music? Graphic scores may reveal density and/or audibility, but they cannot reveal what an individual may be *feeling*, for the form of eccentric-*sounding* music cannot be deciphered due to the virtue of its inaccessibility. Without tonal or rhythmic patterns or expectations, the aesthetic experience needs to both reflect the sonic reality but also the cognitive journey.

III

The problems of Stockhausen's "moment form" and its variants (mentioned in section I) are twofold, for it dismisses the concept of a cognitive journey and denies the philosophical concept of *intentionalism*. Let me explain both of these in turn. First, while the mind does not think entirely linearly, it does ultimately follow a narrative. To follow a non-linear non-narrative would be distracting and impossible; to follow a non-linear narrative would not be. It is partly a matter of awareness: Once a listener realizes that they are listening to a narrative, they no longer need to comprehend the sounds any more than they need to understand a *de stijl* painting—they just need to know *what* the artist wanted to express and *why* they wanted to express it. Not all music has a perceivable form, but all music speaks a story; if the form cannot be perceived, the listener must have a relatable narrative provided. Without such a narrative, formality does not cease, but rather, it remains inaccessible, and then the content must be appreciated for its individual elements; usually, however, it is not appreciated at all.

With this in mind, it is clear that musical analysis cannot rely on appearance but *experience*, and so "moment form" is not an acceptable denotation for any sort of music; on the other hand, a "narrative form" could be. Hindrichs Gunnar's article "Towards a General Theory of Musical Works and Musical Listening" argues for such an experiential analytical method, and argues for an *aesthetic* ontology to analyzing music, rather than scholarly ontological approach—the latter of which he claims is "gobbledygook to the aesthetic understanding."[7]



Example 1a and 1b. Waveforms from a sonata by Beethoven and a fixed media work by the author.

Indeed, standard musical analysis likens a musical score to a painting: What you *see* is what it is, which (as any composer can attest) is not necessarily the case, and for those who compose for fixed media and for aesthetical purposes, this is entirely untrue. What one *hears* is what determines the music, and so Stockhausen's troubling term "moment form" is entirely contrapposed to realtime listening. See examples 1a and 1b, one of which is a waveform of a Beethoven Sonata, another of which is a waveform of a fixed media work by the author. Clearly, one needs more than simply a waveform to determine the nature of a piece of music, no matter how long, short, tonal, or the like. Even colorful graphic scores (just search for "graphic score" online, and you will see the variety)[8] express a visual interpretation rather than an inner experience. While these scores *do* have an emotional impact on the performer, the listener—unless they are reading along with the score *and* interpreting the imagery similarly to the performer—will still sense something that cannot be represented graphically, but only descriptively.

Secondly, the term "moment form" implicitly denies the philosophical concept of *intentionalism*. A composer's compositional methods must in some way be purposeful, and for something to have a purpose, it has an intentional organization. Even John Cage's *4'33"* or La Monte Young's *Compositions 1960* all have a governing principle, making them absolute ideas, no matter the results. "[Connection and] disconnection mean something,"[9] and, if I define "form" or "order" as *a compositional procedure utilized to create a set of guidelines*, then it is philosophically impossible for a composer to actually "compose" something without any formalization in one respect or another. Even Cage determined the *I-Ching* would dictate the outcome of his *Chance Music*. These pieces may lack a coherent narrative, but there still is a narrative behind the form, and the music as a whole is a "narrative," and much more than simply a bunch of "moments."

Many would object that my argument is merely a connotative difference, and that the aforementioned works *sound* as devoid of formality as they appear, and a narrative means different things to different people. It may be so; but integral serialists face the same aesthetical challenges. I respond that neither the formal approach, the final product, nor the objective sounds represent the composition; it is the *reaction* desired by the composers from their intended audience as well as the audience's overall perception. To satirically summarize the arguments, integral serialists wanted people to appreciate their organization, chance composers wanted people to challenge the idea of organization, and the experimental eclectics wanted people to appreciate their organization of disorganized sounds. The populace adds a fourth category, where they want organization of easily-identifiable sounds. But is that all they want?

IV.

In music's seemingly endless progress toward atonality and a purely sonic art, two major events of the past century should strike us as no less than miraculous: First, Jazz and in particular British/American Rock became a sort of "neo-Common Practice Period," a movement that completely overturned the philosophy of music's eternal evolution. Minimalism soon followed, and the high concert art became untenable in the mainstream concert industry. Second, and perhaps more significant, was the full acceptance of atonal music in the world of film scores and video games—a world in which it did not succeed Common Practice music, but rather complimented it. Examples abound: Abstract music accompanies film scenes that are understandably sinister, mysterious, exotic, or extraterrestrial. Conversely, more conservative and approachable music usually accompanies events to which we can particularly relate or appreciate, such as romance and security. Abstract music often represents the clearly mysterious scenes, while conservative music tends to depict the fringes of accessible and attractive ones.

This is not simply a stylistic reasoning, though, but a thematic one. Compare, for example, the tonal restlessness in Jerry Goldsmith's score to *Chinatown* (1974)[10] with John William's score to *Star Wars* (1977ff.)[11] to find how their orchestrations color the mood of the films. The fact that both these films are representational also permits the music to be of secondary importance, whereupon the audience perceives the scores as commenting on the film, not dominating the action. A similar comparison could be Sci-Fi and serious works such as Babbitt's *Philomel* (1963). Similarly, video game music often borrows colloquial styles and sounds to introduce characters, scenes, and omens. Alan Elkins in "Musical Form and Gameplay Context in the Japanese Role-Playing Game" makes such information clear. While much of the music is tonal and periodic (for both aesthetical and technological reasons), certain scenes such as "military music" contain snare drums, while "dungeon themes" tend to feel circular and aimless, underscoring the tasks at hand for the gamer.[12]

This interdisciplinary phenomenon is not new with the movies or video games, either: Consider the eclecticism present in Richard Strauss' opera *Elektra*, where he fuses late Romantic Expressionism with Mozartian elegance, a strange combination that makes perfect sense when performed as an opera rather than a concert work. Look even earlier, such as Monteverdi's eclectic opera *Orfeo* (1607), where he uses a myriad of timbres, harmonic relations, and counterpoint to underscore the various scenes. Ballets, too, provide visual complements to the music, and without any words. This last point could even be taken a step further to Mendelssohn's "Songs Without Words" and the post-Wagerites' symphonic poems, where only the titles and program notes guide listeners on the subject material. These, too, tend to be understood irrespective to their accessibility or angularity since the titles and narratives are representational and familiar.

In short, abstract music compliments certain emotions portrayed through representational visual elements and/or titles, whether still images or videos. Note that I said, "*representational* visual events and/or titles." Nonrepresentational visuals coupled with abstract music would yield the opposite result: As noted in Uusitalo et al., people tend to analyze abstract visual art with fewer fixations but more time spent on each fixation, thus implying they tried harder to understand different elements of the art, but did not know what it was about.[13] By extension, only *familiar* musical elements assist the analysis of nonrepresentational art. As stated in *Rhythm as Function*[14] and referencing several other theorists, multitasking always detracts, and so one can appreciate novel tasks more if and only if one or more of the other tasks can be performed autonomously.

V.

If titles, representational visuals, and tonally- and/or rhythmically-teleological music makes works more accessible to the populace, what can composers do to communicate more effectively to audiences? Gunnar notes that there are four kinds of interpretations people commonly experience: "Literal" (what is says), "Allegorical" (what it really means), "Tropological" (what the reader associates with it, or what it means to the reader), and "Anagogic" (for what the reader can hope through its transcendent message).[15] While the first two are familiar to most people due to historical critical methodology, the other two—while familiar—are oft-neglected in research. In particular, the "Tropological" category is critically important in musical listening, and perhaps what is lost in more abstract music. If people were asked to associate music with something, they may understand it better. Perhaps that is why visual arts with narratives or implicit narratives (within the title, subtitle, etc.) are often better understood.

One effective tool is to provide catchy, descriptive, and/or poetic titles. If the title takes a second to digest, that may compliment the musics angularity as a puzzling game, not an alienation from postmodernism. This certainly provides a segue into much of the Medieval *chansons* and Renaissance *madrigals*, as well as modernist works such as Schoenberg's *The Hanging Gardens of Babylon*. When the listener encounters unfamiliar musical jargon, familiar or attractive phrases can turn the experience from an affront into an adventure.

Some composers find such a compromise to be demeaning to their work. Like most other personas, this is nothing new: Baroque composers often titled their instrumental works generically; Brahms advocated for "absolute music" in contrast to the operatic and cinematic "Wagnerites;" Georg Friedrich Haas and other living composers want their audience to engage with the music, not limiting its potential to a programmatic title. Yet Claude-Jacque de la Guerre, Brahms, and their contemporaries maintained an aesthetical anchoring that their listeners both then and now take for granted, while Haas and his contemporaries have different audiences in mind, particularly the avant-garde academics and Eurasian arts organizations. Nonetheless, most listeners probably have a more positive experience deciphering familiar imagery (e. g. Schoenberg's *Hanging Gardens*) or comedy (e. g. Berio's *Sequenza V*) than digesting generic titles or references (e. g. Stockhausen's *Mikrophonie I* or Haas' *Limited Approximations*). Uncompromising approaches may have great value for the composer, but it can negatively affect their public reception.

Another possibility is interdisciplinary art and multimedia. As mentioned before, composers writing in the genres of opera, ballet, musical theatre, film scores, and video games utilize abstract music to great effect, evoking unfamiliar or undesirable experiences for which traditional tonal music would pale in comparison. In addition to these, one can compose music to a slideshow or personal photographs, videos, or other accessible forms of visual art. While the field of interdisciplinary art, too, contains creators who prefer to make their projects an end in and of themselves rather than a means to a familiar emotion or experience, they represent only one of many avenues for those interested in mixed media.

Yet an additional possibility is to present abstract art as part of a lecture-recital, whereupon the sound artist(s) explain in plain language their experiences writing the music, whether the experience result in an emotion or in spite of emotion.

One final possibility (although there are certainly countless others) is composing based on the concept of the aforementioned "narrative form," which can be especially helpful for composers uncomfortable with nontonal soundscapes by providing a freedom that is enhanced through loose guidelines. Consequently, composers can take esoteric sounds and turn them into a familiar palette, and the new sounds go from *a posteriori* to *a priori* through this theme of experience and existence. Such composers could create etudes using a serial row of timbres, a story where each character represents a different sound, or with a similar approach, which allows them to organize sounds that are initially unfamiliar to them—and the populace. There are countless ways for composers to exercise aesthetical control in their music, and these have been merely a few suggestions.

VI.

Such an approach, especially if effective, should also be applied to musical analysis, especially if the music theory curriculum is to change in order to feature contemporary composers in a relevant manner. Therefore, it is paramount for theoretical analyses to be based primarily on aesthetical relatability, and to argue why we need aesthetic experience as the primary criterion in musical analysis. In essence, analysts ought to incorporate references familiar *experiences*, not simply motivic constructs, to determine the unification principles of any given work. The problem with a motivic approach is that many theorists have a more academic and partial disposition toward modern music.

Although such a concession is antithetical to what film composers and psychologists have found to be possible in the realm of multimedia, a storylike analysis of integral serialism and chance music seems to be hopeless, insofar as the composers often provided no epic to follow, and to suggest an unproven backstory would be risky. Music analysis is a *theory*, though, and scholars must be willing to experiment with different narratives, drawing upon extramusical clues such as the life of the artist at the time of the composition and the simultaneous cultural events. Stockhausen and Boulez, for example, were in Western Europe during WWII and the Cold War, and their respective locations likely made the latter an iconic symbol of postmodernity for which their music could represent in a covert manner. While there is no way to prove such conjecture, it is one that could shed light on such extremely esoteric music. Indeed, Soviet music is almost always analyzed through the lens of culture, and so why cannot abstract form be analyzed the same way in Western and other cultures? While these various cultures maintain important differences, there exist many important similarities, including some aesthetical ones, as exemplified through some of the similarities of popular music and art throughout the world. If this is true, then there are certain values that can translate worldwide in which analysts can begin to experiment with manners to uncover human connections with abstract music.

Conclusion

The populace clearly does respond to abstract music, but only when it can be associated with something familiar and meaningful. Neither is the composer at fault for creating music that is formalistic, experimental, or the like. However, it is on the onus of each composer to determine *if* they want to make their work more or less accessible to the average listener, and if so, how. Likewise, if music analysts want to make integral serialism more immediately relevant to students and peers, it is expedient to attempt an aesthetical, experiential approach, a starting point for this article has suggested in the previous section. Notwithstanding, this topic is far from complete. Further research on this topic includes one or more surveys comparing the role of titles, representational art, and musical examples within the same study. Previous research has shown that titles complement art and music in both representational and non-representational contexts, but not all three in tandem. In conclusion, though, it is clear that abstract music is only as abstract as we want to be, and is highly dependent on the context, purpose, and familiarity of the musical as well as the extra-musical components of any given work.

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Teleology and Unity in Barry Truax's *Riverrun*

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Barry Truax's *Riverrun* (1986) is generally remembered for having been the first piece of electroacoustic music to use real-time granular synthesis in its composition. This was a monumental technological achievement—however, I argue that the success of this piece reaches beyond the mechanics of its sonic contents. Truax's seamless integration of soundscape and narrative in *Riverrun* amounts to a unified and teleologically satisfying aesthetic experience. *Riverrun*'s narrative—the journey of water flowing from a trickling stream all the way to the sea—bears an inherent telos that is realized in part through micro- and macrostructural uniformity as well as the consistent use of contextually appropriate sound materials.

Keywords: Musical narrative, Teleology, Granular synthesis

Barry Truax's *Riverrun* (1986) was the first piece of electroacoustic music to use real-time granular synthesis in its composition using the DMX-1000 Digital Signal Processor (Helmuth 2006). The piece represents the journey of water in various states of aggregation and intensity, starting from a trickling rivulet and eventually reaching the sea.

When *Riverrun* appears in the relevant literature, it is most often discussed for its technological achievements and nuances. Less often is the piece discussed for its broader artistic effectiveness or the consistency of its aesthetics. This paper examines the rich relationships between *Riverrun*'s narrative and its accompanying soundworld, namely the integration of narrative and representational sound as well as the realization of the narrative's telos through the cohesiveness of compositional micro- and macrostructures.

Teleology

Riverrun's narrative bears a teleological implication. In philosophy, teleology is concerned with 'telos' (i.e. something's purpose, end, or reason for being). An acorn is the classic Aristotelean example of a telic entity—its inherent purpose (its end) is to become an oak tree. Teleology has been and continues to be a controversial philosophical concept, especially in the natural sciences and metaphysics. However, reappropriating the idea for aesthetic arguments does not elicit the same ontological and scientific criticisms that have been raised against its legitimacy in these and other philosophical and scientific areas.

Riverrun is not unique for bearing a telos. Many pieces of music are telic and, like *Riverrun*, realize their teloses sonically. However, not all sonic realizations of teloses are as precisely representational as the granular soundworld of *Riverrun*, and thus are arguably less successful with respect to their telic aspects. The sonic realization of *Riverrun*'s telic narrative is unique in that it is achieved by thoroughly integrating narrative and sound.

Truax describes the narrative of *Riverrun* in the following manner:

> *Riverrun* . . . modeled itself, as the title suggests, on the flow of a river from the smallest droplets or grains, to the magnificence, particularly in British Columbia, of rivers that are sometimes very frightening—they cut through mountains, they have huge cataracts, and the eventually arrive at the sea. (Truax 1990: 124)

Truax's suggestion that the piece is modeled on the migration of 'droplets' indicates that its ultimate representational purpose is to eventually disembark, or "arrive at the sea." Thus, *Riverrun* has as its telos the arrival at a certain destination in space. This telos is eventually realized—the trickling water droplets (0:10) transform into rushing rivers (7:15; 13:01) and ultimately reach the ocean (15:58).

Unity

The structural unity of *Riverrun* at both the micro and macro levels contributes significantly to the successful realization of *Riverrun*'s telic narrative, as does the relevance of representational sonic contents as invoked by the imagery of the narrative. It is not enough for the telos to be realized abstractly—that is, for abstract sonic contents to migrate from 'Point A' to 'Point B'. Rather, the telos must be realized *in context*, in this case requiring well-approximated sonic representations of water sounds. Curtis Roads (2019) discusses the relationship between musical narrative and contextualized sound objects in 'What is Sonic Narrative?':

> Only a contextually appropriate sound serves narrative structure. . . . Inappropriate sound objects and dangling phrases inserted into a structure from another context work against their surroundings. If they are not pruned out of the composition, their presence weakens the structural integrity of the piece. Even a small anomaly of this kind can loom large in the mind of listeners. An inappropriate sound object or phrase can cancel out the effect of surrounding phrases, or call into question the effectiveness of an entire composition. (Roads 2019)

Roads claims that the efficacy of a musical narrative can become compromised by the presence of "inappropriate" sound objects. The efficacy of *Riverrun*'s narrative and thus the realization of its telos can in part be attributed to the appropriateness of its sonic contents, or the relevance of the material to the narrative. In this regard, the realization of the telic narrative necessitates the ubiquity of contextually appropriate sound objects. Luckily for Truax, granular synthesis is well-suited to the emulation of natural sounds. Truax's granular processor allows controlled parametric randomization, a stochastic component that approximates the randomness of real water sounds (Helmuth 2006; Truax 1990). In the real world, turning on the water in the shower will produce minutely different sonic results each time—the water will bounce off of the floor at different angles, the density of its flow will subtly vary, and so on. However, the extent of such differentiation is limited to a certain range predefined by the bathroom plumbing and the shower mechanism—for instance, the material of the shower floor cannot change, nor can the number of holes in the showerhead. This sonic profile is therefore only stochastic insofar as it is allowed to be by certain parameters. Parametric randomization in granular synthesis works in the same way, allowing the composer to predefine the range of randomization by parameter. For instance, in *Riverrun*, Truax defines (and redefines in real time) given ranges within which grain frequency randomizes (Truax 2013). To approximate the sound of a trickling rivulet at the beginning of the piece, Truax defines a wide frequency randomization profile within which sparse grains vary. For more powerful bodies of water (e.g. 7:15), randomization is increased in both frequency and grain duration as the grain density proliferates.

The uniformity of ungranulated source material (sine and FM waves) further contributes to the sense of unity in *Riverrun*. The waveforms used to generate the granular content are not necessarily discernible by the listener, but if these waveforms were to be continuously replaced with different waveforms, the difference would be noticeable. For instance, if the ungranulated parent-tones for the quasi-sustained frequencies at 8:33 were replaced with saw waves, the relevance of these sounds and their relationship to the piece at large would be called into question. This is an important aspect of the soundworld because the listener is led to believe that, in the world of *Riverrun*, water is supposed to sound like sine or FM grains. The continuous deluge of sine and FM grains ensures the listener that despite the futility of an attempt to aurally discern these sound objects, the sounds that are heard are indeed related. The uniformity of source material creates an in-world criterion for sonic appropriateness whereby sonic microstructure (waveform) must relate to the broader macrostructure (narrative form).

Riverrun's soundworld never enters a state of rest—it is "in a constant state of flux, much like environmental sound generally and water sound in particular" (Truax 1988: 25). This is in part because the poetics of motion embedded in the imagery of flowing bodies of water necessitates an accompanying sense of motion in the music. Throughout the piece, and particularly in sections where the grain density is high (e.g. 5:14), grains are constantly adopting new pitch identities and durations at a dizzying pace through parametric randomization. Curiously, however, the perpetuity of rapid motion results in a sort of perceived stasis. Perpetual motion is so integral to the fabric of the work (and to the reflection of the narrative) that the unrelenting dynamism inherent to such dense granular processing becomes aurally normalized. If the thousands of grains were to occasionally be substituted with a few simple oscillators or even acoustic instrument recordings, the artificial stasis and general sense of unity afforded by continuous change would be compromised by segmenting the piece into distinct sections (i.e. granular sections and non-granular sections).

Conclusion

Truax's achievement of being the first composer to implement real-time granular synthesis was monumental. However, the implementation of a new technique does not result in successful music by default. This is not to suggest that *Riverrun*'s compositional success is entirely separate from its technological ingenuity, but instead to draw attention to Truax's impressive integration of a telic narrative with a contextually appropriate and unified soundworld. Rather than work against or ignore its teleological aspect, Truax embraces the guiding principles of the narrative and allows the contents of the soundworld to emerge from its imagery and telic implications.

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Listening to Emojis through Sonification

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This article presents sound-generative methods through image sonification in the audiovisual project of the author: titled “48 Emotions project”. Sonification is data rendering into an audible domain. The source of sonification for the project investigation is the selected emojis, which represented the user’s emotions through emoji’s graphics in .png format. This study and the artwork employed four sonification techniques: Audification, Parameter mapping sonification, Auditory Icons, and, Earcon, to explore the results of sound-generative for artistic purposes. Briefly, processes and results of sound-generative will be presented in this article.

Keywords: Experimental music, Sonification

Sonification background and related works

As an artist who made a musical composition or the art of sound organization, composers compose a piece of work by interpretation and transform an abstract-form of imagination or inspiration into a musical piece. A process of transformation of an abstract-materials into a musical composition is relevant to sonification, that concerned with a process of alteration of any abstract materials into an audible domain.

The early definition of sonification was given by Kramer: “representing data with non-speech sound” (Kramer 1994), and “sonification is the use of non-speech audio to convey information” (Kramer et al 2010). Later, several researchers had developed and extended the definitions as “the technique of rendering sound in response to data and interactions” (Hermann et al 2011), and a recent definition which comprehends the purposed of arts: “Sonification is any technique that translates data into non-speech sound with a systematic, describable, and reproducible method, to reveal or facilitate communication, interpretation, or discovery of meaning that is latent in the data, having a practical, artistic, or scientific purpose” (Liew/ Lindborg 2019).

Sonification is widely used for interdisciplinary purposes, which contrasted from the early state that is mostly employed for scientific use. The “Geiger counter”, is one of the examples of sonification exploited. This tool has been using for radiation detection by having sonified the intensity of radiation into sound. (Dombois/ Eckel 2011: 304) Another example is the “stethoscope”, a medical tool for diagnosis heart or breathing (ibid.). It still in use for medical purposes until today.

For artistic purposes, several artists exploited sonification in their artworks such as Andrea Polli, who employed climate change data as a sonification source. Her goal is to create artwork and raise awareness of global warming (Polli 2016). Marty Quinn, who employed scientific data for artistic purposes. One of the distinctive works such as The Climax Symphony (Quinn 2001). Christina Kubisch, who explores and sonifies electrical fields (such as street walking, electric devices, etc.) which exist in everywhere by let participants explored in several sites, and the results of magnetic field sonification delivery to participants by her custom headphones (Dombois / Eckel 2011: 319; see also Kubisch 2016). Moreover, there are several artists who are active and employ the data sonification in their artworks which is not mentioned in this article. However, with the theme of creative and artistic research, recently, the author has been working on audiovisual projects: 1(X)MB (Janbuala 2019) and F(r)ee Road (Janbuala 2019) that exploited sonification for the artworks.

In the “listening to emojis project”, four methods of sonification are employed: *audification*, that directly renders the input source into the audible range, *parameter mapping*, that maps the input source into musical properties, and, e*arcon*, the method that interprets and designs a short musical motive from the sonification sources, and, *auditory icons*, the method that interprets and sonifies metaphoric relation of sonifying objects. Further explanation will be found in the next part.

Listening to emojis project

The project aims to create the artwork from image sonification and to make an interactive experimental-audiovisual piece that all processes performed by the computer for one performer. The piece is titled “48 Emotions” (Janbuala 2020).

Selecting Emojis

The project employed emoji(s) which represented a user feeling instead of word expression. It has been widely used in modern life through a smartphone or in social media uses. Author had selected forty-eight emojis for the artwork. Each of the selection represents different graphics, and descript in different emotions. The use of emojis is in the format of the ".png" file, and the scale of each emojis are 28 x 28 pixels, 144 x 144 pixels, and 300 x 300 pixels which each of resolution gave a different affected to the sound render process. In each pixel's location contains color's data ARGB (as the order of Jitter). The range of color's data is between 0 – 255 which rescale the data into the range of 0 – 1 for sound generative purposes.

Figure 1. Sample of selected emoji "Smiling face with open mouth" by 28 x 28 pixels.

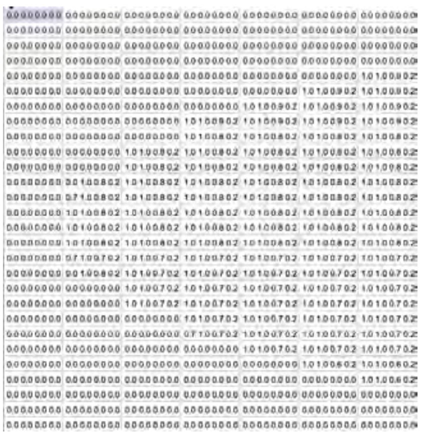

Figure 2. Color data (ARGB) inside the smiling face with open mouth emoji.

Sound generative process

Two kinds of data are used for sound generative through sonification: still-image and moving images(video). What made moving images data different from still image? For a still image, the data output is static information which, contrary to moving images which are streaming of data and they are updated on the rendering time. For the sound generative process, sonification techniques are employed through the custom patch on Max (Cycling'74) by author. The custom patch works by extract the color's data (ARGB as the order of jitter) from the video input into the streaming of data. The sonification input source is color data from the moving images input that included the placement and composition of emojis and obstacles, and four methods are exploited for sound outcomes. Firstly, Audification, the streaming data directly affected to sound generative process which most of the sound outcome of the project represented as noise sound. This technique direct transformed color's data of emoji(s) into a sampling of sound waves before rendering into the sound (see Dombois/ Eckel 2011: 301). Secondly, Parameter mapping is used for mapping the streaming data into musical properties (Grond/ Berger 2011). This project employed the streaming data as an ostinato motif. Instead of rendering all streaming video data, this artwork was designed by measuring the data stream in the specific interval (snapshot) which able to capture less-activity data before rendered into an ostinato motif through four Triangular-wave generators. Thirdly, earcon, forty-eight short motifs were composed of my interpretation from emojis. This method used a different approach of composing, it does not lie on color's data stream, but, depending on the composer design through four Sine-wave oscillators (see McGookin / Brewster 2011). Fourthly, the auditory icon method is exploited by the interpretation metaphoric relation of emojis (see Brazil / Fernström 2011). In this project, emojis are interpreted by design a short sequence of sounds in which author employed speech synthesis "Kanya voice" from the apple computer for sound generation, and the result came up with forty-eight sound designs (see the appendix). Further explanations of sonification techniques can be found in the sonification handbook (Hermann et al 2011).

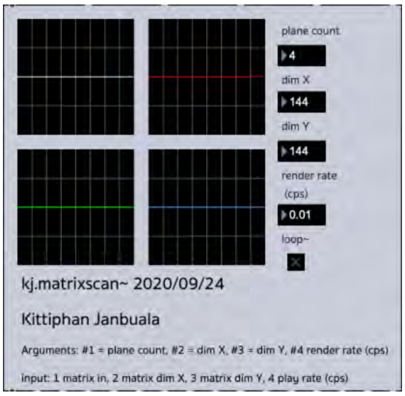

Figure 3. Custom sonification patch by the author: the purpose of the patch is to extract color data for parameter mapping sonification, and audification.

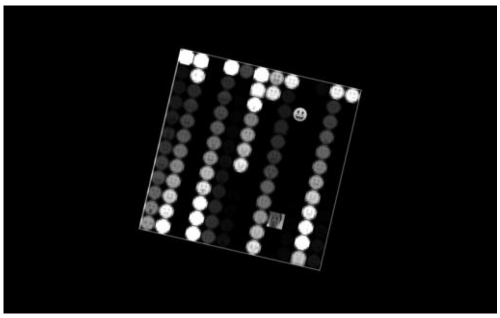

Figure 4. Example of the artwork.

Live interactive design

The artwork's intention is live control by the performer. The role of the performer is to control the user-object, to avoid the obstacles, and, to reach the target emoji for the process to the next emoji's events. The control user-object was designed by the use of computer keys (AWSD), performer able to animate the control-object in four directions: A for moving left, D for moving right, W for a moving upward, and, S for moving downward. The webcam camera is also employed for interactive purposes. The performer's face is represented as the control-object. The whole streaming of moving images outputs, every move is affected into the visualization and sound generative process. S

Figure 5. The control object keys.

Conclusion and further develop

Sonification is the data rendering process into an audible domain and initially, has been widely used in scientific fields. However, sonification is attracted to a creativity domain. Several artists have been exploited sonification for artistic purposes. They have their aesthetics in creativity based on data rendering techniques. The outcome of the artworks is varying and dependent on the artist's intentions. In this project, the source input exposed the potential of creativity. The aim of the artwork is not to make a pleasant piece of musical composition but author has exploited sonification as a sound generative methodology. Sonification is not the best method for making a musical composition or sound art, but the intention of creativity is significant for artists. However, there are some points to improve for future development such as a sound timbre which too restricts the sonification sources (emojis) in this artwork and dynamics of sound design. The parameter mapping techniques for creativity need to explore the possibilities for artistic and aesthetic purposes and further exploited in musical properties such as the development of motif, dynamic, panning, filters, etc. A work systematic and sonification plan for the artwork could continually develop for a variety of sound generation and impression of the artworks.

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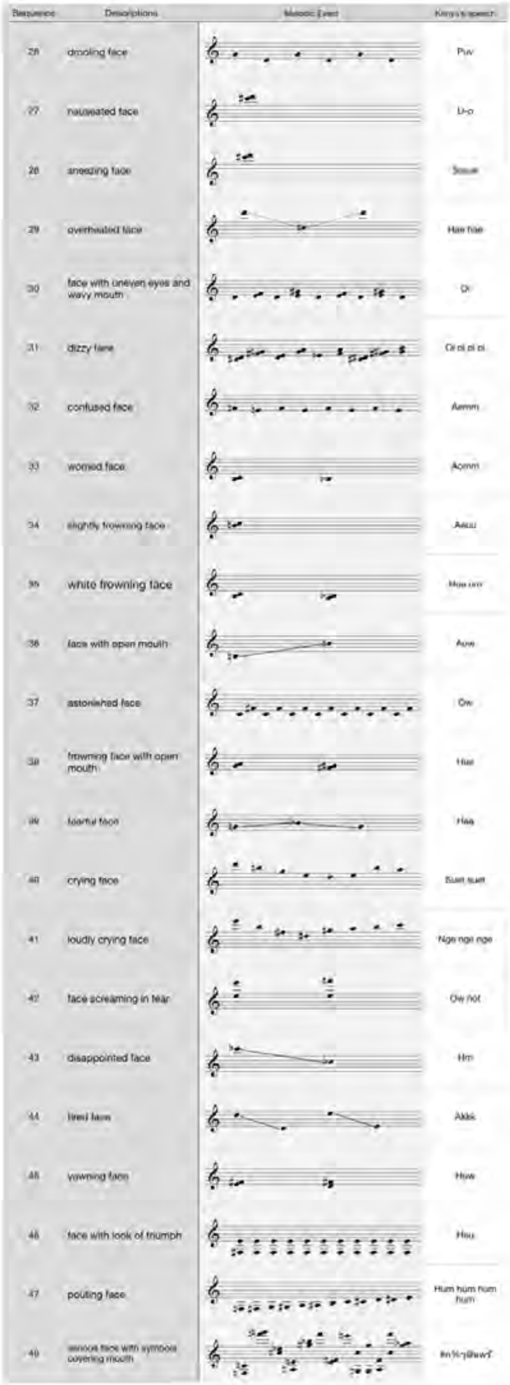
Appendix: Earcon designs, and Auditory Icons designs

Sequence	Descriptions	Melodic Event	Kenya's Speech
1	smiling face with open mouth		Ha
2	smiling face with open mouth and smiling eyes		Aha
3	grinning face with smiling eyes		Hae hee hee
4	smiling face with open mouth and cold sweat		Ha ha(down tone)
5	face with tears of joy		Ha huee huee huee
6	slightly smiling face		Nguem
7	smiling face with heart shaped eyes		Wow woo woo woo woo
8	face throwing a kiss		Chup phew
9	kissing face		Chup
10	kissing face with closed eyes		Chssssp
11	kissing face with smiling eyes		Um chup
12	face savouring delicious food		Paeb paeb
13	face with stuck out tongue		Baaae
14	face with stuck out tongue and tightly closed eyes		Hee baae
15	hugging face		Um hm
16	smiling face with smiling eyes and hand covering mouth		Hu hu hu
17	face with finger covering closed lips		Shu shu
18	thinking face		Ummmm
19	neutral face		Um
20	expressionless face		Hm
21	face without mouth		Jut jut jut
22	smirking face		Asu hsu
23	unamused face		Ummm hsu
24	face with rolling eyes		Hmmmm
25	grimacing face		Garr garr



Sequence	Descriptions	Melodic Event	Kenya's speech
26	drooling face		Puv
27	nauseated face		U-o
28	sneezing face		Sssue
29	overheated face		Hae hae
30	face with uneven eyes and wavy mouth		Oi
31	dizzy face		Oi oi oi oi
32	confused face		Aemm
33	worried face		Aomm
34	slightly frowning face		Aeuu
35	white frowning face		Hoe oo
36	face with open mouth		Auw
37	astonished face		Ow
38	frowning face with open mouth		Hae
39	fearful face		Haa
40	crying face		Suet suet
41	loudly crying face		Nge nge nge
42	face screaming in fear		Ow hot
43	disappointed face		Hm
44	tired face		Akkk
45	yawning face		How
46	face with look of triumph		Hsu
47	pouting face		Hum hum hum hum
48	serious face with symbols covering mouth		#n%-j@sw$

Virtual 3D Environments as Composition and Performance Spaces[1]

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In the present text, I will reflect upon the composition of works that use virtual 3D environments in which the performers are represented as interacting avatars. In particular, I will explain the musical possibilities offered by this work with virtual environments, detailing the effects that the design of virtual topologies has on the interactive sound sources and sound events contained in these topologies. I will focus particularly upon how performers can musically influence said effects by navigating with the avatars acting within the topology.

As a point of entry, I will start by investigating basic aspects of musical work with space and movement using the example of Tom Johnson's composition *Nine Bells*. I will then use my own composition *Kilgore* (2018), as a case study for my more detailed examination of this topic. After analyzing general aspects that play an important role in compositional work with 3D environments, I will embark upon a discussion of questions concerning the representation of performers in the virtual space. Following a discussion of 3D environments' analogies to instruments and scores, I will finally investigate a range of concrete issues and methods related to audiovisual composition using virtual spaces.

Keywords: Virtual 3D Space in Concert-Based Works, Composing with Space and Movement, Representing the Performers in the Virtual Space

Previous Applications of Virtual 3D Space in Concert-Based Works

Recent years have seen a remarkable increase in the use of game engines for musical purposes. Thanks to software such as Unity (Unity Technologies) or Unreal Engine (Epic Games), designing interactive 3D environments is now easily accessible, while only a few years earlier the associated technical challenges were much more significant. Besides a more general trend in contemporary composition to expand musical practices to various other media (Ciciliani 2017), it seems plausible to attribute the strong increase in the popularity of these softwares to its relative ease of use and—last but not least—low cost.

The history of media art includes various examples of projects in virtual 3D spaces that show a strong commitment to musical aspects, such as *Osmose* (1995) by Char Davies, *q3apd* (2002/03) by Julian Oliver and Steven Pickles, and *Fijuu* and *Fijuu2* by the same artists (Oliver and Pickles 2008, p. 430). In this summary, however, I will mainly consider the use of 3D space in works based on performances in concert settings, since this is the focus of the present chapter.

Described as a graphical programming environment, *The Audicle* can be regarded an interesting predecessor to the artistic employment of 3D space in concert settings. It was developed by Ge Wang and Perry Cook (2004) as an editor, compiler, virtual machine, and debugger. More significantly in this context, it includes a carefully and aesthetically designed 3D environment that visualizes computational processes and responds to real-time programming. It offers an aesthetic spatial experience in order to guide design decisions and make processes more comprehensible.

Composer and researcher Robert Hamilton published extensively on his work with game engines and virtual 3D space. In 2007, he already investigated possibilities for tracking avatars in 3D space and using streamed data to control musical events (Hamilton 2007, 2008). Since then, he has also produced several remarkable works that employ virtual 3D space in concert settings. In particular, the works he created in collaboration with Chris Platz, such as *ECHO::Canyon* (Hamilton 2014) and *Carillon* (Hamilton and Platz 2016). More recently, he has focused on building virtual instruments that are played by musicians wearing VR headsets, as in his virtual reality string quartet *Trois Machins a la Grâce Aimante*. This work, however, does not offer navigation in the 3D environment.

In 2007 the NOVARS research center was established at the University of Manchester, UK, specializing in Electroacoustic Composition, Performance and Sound Art (Climent 2008). From the start, the center was run by Ricardo Climent, who began to work with virtual 3D environments in the following year with his installation *Ho*. In the wake of this project, Climent composed a series of concert works based on virtual 3D space, starting with *Xi* in 2012 (Climent 2012). Furthermore, working with immersive space became one of the core research areas of NOVARS, leading to various PhD projects based on 3D space and game engines, such as Jose Ignacio Pecino Rodriguez's dissertation (Pecino Rodriguez 2015).

It is interesting to note that works using 3D environments have recently also found their way into composition competitions that in the past focused mainly on instrumental music. In 2019, composer and media artist Remi Siu was one of five finalists of the prestigious GAUDEAMUS award for young composers. His competition entry was *new notations* (Siu 2019), a multiplayer 3D environment that was performed by four musicians of the Nadar Ensemble. It thus seems safe to say that after one and a half decades of experimentation in the niches of mainly academic electronic music, today composition with 3D environments has found its way into the mainstream of contemporary music.

Composing with Space and Movement

Usually, the concept of 'composing with space' is understood as the purposeful positioning or movement of a sound event in a plane or three-dimensional space. My reflections are also concerned with the distribution of sound events in space, but here one important feature is that this spatial configuration can be experienced in a virtual space through performers' movements. This section of the text will examine the interaction between the spatial configuration of a 3D space, the distribution of sound sources within that space, and the kinds of movements carried out by the actors. I will start with an analysis of Tom Johnson's composition *Nine Bells* (1979).

Even though this piece makes no use whatsoever of virtuality or other technologies, it is a vivid illustration of some of the basic principles of composing with space and movement. The only sources of sound in this work, which lasts for just under an hour, are nine bells. They are positioned evenly in three regular rows of three bells on a square area measuring just under 4x4 meters. The composition is made up of nine parts. In each of them, the performer moves around the bells over and over on precisely defined trajectories, striking them according to specific defined patterns. Each part uses a different movement pattern, which then characterizes the musical event. The melodic material is formed by the individual movement patterns, which make certain sequences of pitches possible and exclude others. The movement pattern likewise determines the time intervals between the strikes and thus the rhythmic sequence. It is crucial that the performers move at a constant speed, so that covering a certain distance always takes the same amount of time. Accordingly, it takes longer to reach bells that are further apart than those positioned directly next to one another.

Nine Bells illustrates the principles of composing with space and movement in transparent and concentrated form. The same principles—the interaction of the distribution of the sound sources in the space on the one hand and the performers' movement on the other—are also characteristic of working in virtual 3D spaces. If one aspect changes, this has a direct impact on the other, too, with consequences for the music. If, for example, the position of two bells were exchanged, but the sequence of notes retained, this would lead to a change in the movement pattern and thus also to a change in the time intervals. If we were to replace the regular, symmetrical distribution of the bells with an irregular pattern while retaining the same movement pattern, this would lead to different time intervals. I illustrated the latter case using two computer simulations that are available for viewing online. The first example shows an accelerated simulation of "First Bell," the first part of *Nine Bells*, in a virtual three-dimensional space. The second example shows the same piece, but here the position of three of the bells has been altered. The resulting change in the intervals at which the bells are struck markedly changes the piece's basic musical character.[2] Figures 1a and 1b show the changed positions of the bells.

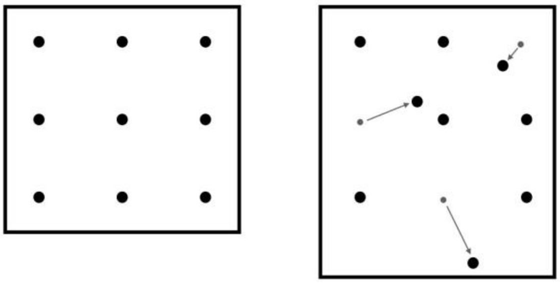

Fig. 1a and 1b. On the left we see the original position of the nine bells in *Nine Bells*, on which the first computer simulation is based (Fig. 1a). The figure on the right shows the changed positions of three of the nine bells (Fig. 1b). These positions were used in the second computer simulation.

At first, the difference between the two versions appears quite straightforward. By changing the distances between the bells while retaining the same movement pattern, the time intervals between the strikes change. However, it is worth taking a closer look at the musical differences: the even distribution of the bells endows the original version with a sense of calm that is already evident in the piece's initial phase, in which only the middle bell is struck at comparatively large intervals. This temporal regularity is conveyed not just on an auditory, but also on a visual level, as in this phase the avatar is already circling four of the nine bells.

The timing of the asymmetrical version could be described as more unsettled or nervous, as the calming equal proportions of the original have been lost. At the same time, the asymmetrical version could also be regarded as more elastic, as the time intervals are expanded and compressed. These expansions and compressions repeatedly result in melodic conglomerations, giving rise to a different sense of melodic emphasis than in the regular original. For example, certain situations take on the emphasis of an upbeat, which was not perceptible as such in the regular version. In my view, the spatial repositioning of the bells has far-reaching musical consequences.

In the following, I will examine to which extent these observations on the reciprocal effect of the positions of the sound sources and the movement patterns in *Nine Bells* can be applied to a virtual 3D space. My composition *Kilgore* will serve as a point of comparison. *Kilgore* is a composition lasting just under half an hour for two performers. In certain parts of the piece the performers play instruments, while in others they navigate in a virtual 3D space using game controllers. In this virtual space, they carry out actions that have both a direct and an indirect musical impact upon the composition. These actions create the work as a whole, and it is thus possible to say that the virtual 3D space is also the composition's performance space. Figure 2 shows what the space looks like from the performers' perspective.

Fig. 2: The performers' perspective while they move through *Kilgore's* virtual environment and interact with sound-producing objects.

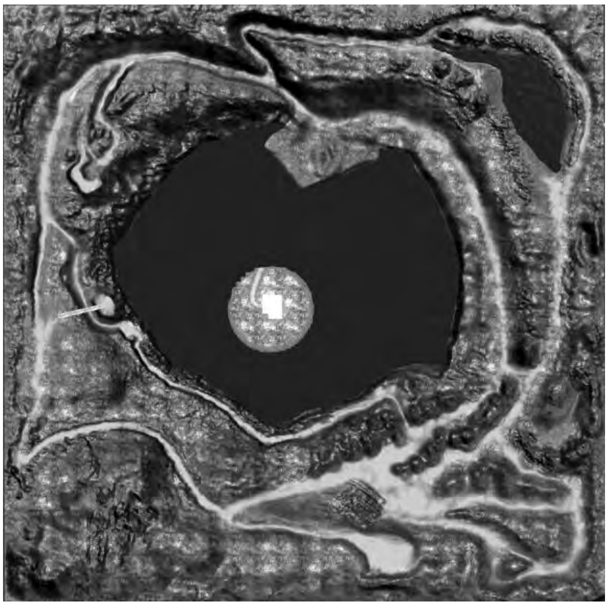

Fig. 3. A cartographic view of the entire virtual space, which measures 500x500 virtual meters in total.

Comparing *Kilgore's* performance situation with that of *Nine Bells*, I first have to point out that in *Kilgore*—unlike in *Nine Bells*—the performers can move around freely using their avatars. There is no set speed of movement, nor are there defined trajectories. Movement is shaped by the environment and the paths it contains. As can be seen in figures 2 and 3, I designed the 3D environment as a mountainous landscape with different pathways, some of which have been literally carved into the terrain. If we now imagine that various musical affordances are distributed within this environment, we can see that, in musical terms, the connecting pathways and separating obstacles define sound sequences and time relations, even though the latter are not precisely defined as rhythmic values, as in *Nine Bells*, because the performers are able to move around freely.

While the bells in *Nine Bells* are distributed across a space of less than 4x4 meters, in virtual space we are naturally not confined by the practical limitations of actual performance spaces. In *Kilgore*, I worked with a landscape measuring 500x500 virtual meters. But what happens if we assume—analogously to the bells in *Nine Bells*—that the sound zones in *Kilgore* are distributed evenly and differ in the quality of their sound, and then reposition these zones? This would necessarily lead to changes that affect the piece's large-scale musical structure. That which manifests as a variation in rhythm and melodic character in *Nine Bells* here becomes a change in formal structure.

We can thus deduce two fundamental insights from the work with movement patterns and sound sources distributed in space, which I will summarize here:

1. The spatial distribution of sound sources shapes a composition's time factor. Certain combinations of sounds become more likely than others and are presented as more obvious. If the distances are shorter, as in the case of *Nine Bells*, the effects affect musical details such as rhythmic configuration and melodic sequence. On a larger time scale, the specific distribution shapes the piece's formal structure.
2. The design of trajectories is directly linked to the previous point. In contrast to the precisely defined movement patterns in *Nine Bells*, when navigating in 3D environments it is customary to allow the actors to move freely within the space. Accordingly, we cannot predict which sounds will occur exactly when and in which combination. Nevertheless, the topology's design determines whether

> certain spatial connections and sequences of sound are facilitated and others made more difficult. Thus we can assume that each decision concerning the design of a 3D environment, such as the inclusion of obstacles and passages, will have indirect or direct musical consequences.

Depending on our perspective, a 3D environment and the sound-generating object it contains can thus be seen either as an instrument or a score. I will return to this comparison in the next section but one, where I will describe an example in which the direct link between the landscape's design and the associated musical consequences is evident.

Representing the Performers in the Virtual Space

As mentioned above, a performance of *Kilgore* is created in a concert situation in which two performers act on a physical stage. At the same time, the virtual three-dimensional environments in which the performers are represented are shown on two projection surfaces.

The game engine Unity has been used to design the 3D environments. The two performers are running two instances of the same environment, while their start locations in the virtual environments are different. All sounds are produced in the software SuperCollider in real time. Data streams with information on the movement and actions of the avatars, and the locations of sound producing objects in the environments are exchanged between the two Unity instances and SuperCollider by using OpenSoundControl (Wright and Freed 1997). While there are a number of different sonic scenarios in the piece, movements of the avatars always produce continuous sounds when moving in the horizontal plain and percussive sounds when jumping.

The performers explore their virtual environments from a "first person perspective." While they themselves cannot be seen in the virtual world as 3D models, their individual perspective and movements mean that they can be identified. I refer to these representations as 'avatars.' While this term is frequently used to designate a person's digitally rendered visible form in a virtual space, I draw on the more general mythological concept of the avatar being the instantiation of a person's essence into a physical body (Scarborough and Bailenson 2014, p. 131). In so doing, I emphasize the presence in another world rather than the question of visual appearance. This justifies my use of the term, even though the form itself remains invisible in the "first person perspective." Accordingly, a major part of the performance is realized in the 3D space by the performers, who move within this space and interact with various sound functionalities via their avatars. Thus the virtual space also functions as a performance space.

In order to make it possible for the performers to experience being present in the virtual space, in *Kilgore* I took the simulation of a realistic situation as my starting point for the piece's visual and the acoustic design. In concrete terms, this means that aspects such as navigation, gravitation and acoustics behave similarly to the way they do in reality—an approach that is also standard when designing computer games in 3D spaces. As far as the acoustic design is concerned, the sounds perceived correspond to the performers' positions in the virtual environment, a phenomenon that Michel Chion describes as "subjective point of audition" in the context of film (1994, p. 90). In the present case, this subjective point of audition is based upon the implementation of the following three elementary aspects:

1. The amplitude of a sound source reduces square to the distance from it.
2. The sound source's position in the stereo image corresponds to the performer's orientation in the virtual environment. This means that if a sound source is located to a person's left, they will hear it from that direction. By using a setup of speakers that expands vertically, the virtual sound source's position on the vertical axes could also be represented accordingly.
3. If one turns one's back to the sound object in the virtual space, a subtle filter is applied, which on the one hand schematically simulates the effect of the external ear and on the other hand accords sounds whose virtual source is not seen lesser acoustic presence.

Starting from this position creates the preconditions for a familiar acoustic experience, which in turn makes it possible for the performers to experience a so-called *virtual presence*, the experience of "being there" (Riva and Waterworth 2014, p. 213). This means that the performers identify with their avatars and experience their virtual surroundings as their primary environment, interacting with and orienting themselves towards them. The precondition for this orientation is the ability to distinguish between a self and an environment that does not belong to that self (Waterworth and Waterworth 2014, p. 593). If we want to enable the performers to experience virtuality as a place into which they are intensely embedded, it is important to design its digital realization—also referred to as *perceptually seductive technology* (Waterworth 2001)—in a way that enables the experience of presence. Parallels to the experience of the real world form the starting point for this.

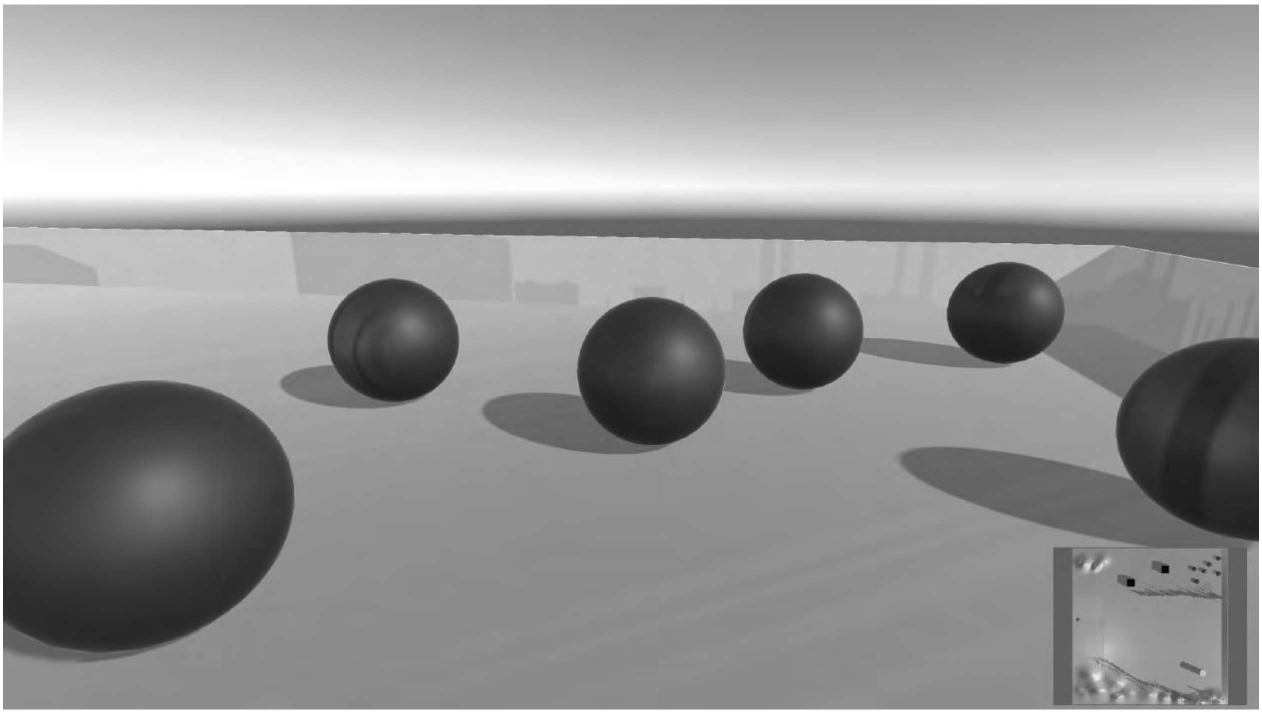

Fig. 4. Examples of a model with six interactive, moveable balls producing different static pitches. Here, generating data that also includes the distances between the balls themselves could provide interesting results.

Interestingly, it is also possible to maintain the illusion of presence in a virtual space even if individual analogies to reality are abandoned: "It has been known for some time that it is possible for virtual reality to achieve a kind of 'sensory rearrangement' resulting in modified experiences of one's own body" (Waterworth and Waterworth 2014, p. 595). This is also referred to as 'maximal binding', "[which] implies that in cyberspace anything can be combined with anything and made to 'adhere'" (Novack 1992, p. 277). This is highly interesting and has hardly been investigated in regard to musical scenarios thus far. In an experimental setup (cf. figure 4), for example, I replaced the third of the abovementioned elementary points, the filtering of sound when turning away, with a manipulation of pitch. This means that in this particular case, all sound sources located behind the avatar were transposed. As the sound sources in this model produced static pitches, rotating around one's own axis in the virtual space resulted in a variation of the harmonic situation.

In my opinion, it is important to note that not only is the virtual presence still maintained in the case of such manipulations, even though a behavior is introduced that no longer corresponds to reality, but also that such manipulations can also be dealt with intuitively as long as the context as a whole perpetuates the basic feeling of 'being there.' In the text's final section, I will investigate the technical aspects of this kind of virtually embodied steering of parameters in greater detail.

The 3D Environment as Score and Instrument

I would now like to discuss more closely the comparison of 3D environments with scores and instruments mentioned at the beginning of this text.

Calling an assortment of, for example, nine bells an instrument would normally not be questioned. Tom Johnson's decision in *Nine Bells* to position the nine bells at a distance from one another does not change the bells' sound potential, but it does shape the way they can be played in a specific manner. This means that the bells' basic function as musical instruments remains intact. When a 3D environment is designed with the aim of offering a certain arrangement of possible sounds, this environment can thus be understood as an instrument.

By contrast, the fact that a 3D environment can also be understood as a score may appear less self-evident. I would like to explain my thoughts on this by way of a concrete example. When designing *Kilgore's* 3D environment, I spent some time smoothing bumpy sections of the paths and ravines along which the avatars usually move, as otherwise the avatars would frequently get stuck behind these uneven patches and need to perform a jump to continue on their path, interrupting the flow of movement. Initially I sought to avoid the gaps produced by uneven sections.

When rehearsing *Kilgore*, however, the following unexpected scenario occurred: at a certain point in the piece, one of the avatars has to move to a position that can only be reached by running through a long ravine. Furthermore, at this point in the piece a functionality is activated that causes objects to fall from the sky when the jump function is used. These objects produce feedback-like sounds when they land. During the rehearsals it became clear that I had not made this ravine smooth enough, which made the avatars get stuck and meant that they could only move forward by jumping. This triggered a large number of the falling objects and their feedback effects. What had initially been an oversight in developing the 3D landscape unexpectedly gave this particular part of the piece a special character of its own. There was no other part of the composition in which the mentioned feedback-producing objects were triggered so frequently. In this particular context, this design 'flaw' provided musical interest and became characteristic of the piece's formal structure.

I have described this scenario in such detail because I consider it an excellent example of how the design of a landscape implicates direct—and, in this case, unforeseen—musical decisions. When looking at such an environment it its entirety, taking its musical characteristics and contingencies into consideration, the analogy of the environment as a score presents itself, in the sense of a legible record and temporal organization of musical events. One key point in this analogy to a score is that the environment and its musical possibilities can be read by human beings, as for example an audiotape is also able to record and organize musical events in time, but does not offer these events in a form legible by humans.[3]

Composing with Rules, Situations and Stimuli

Composition using gaming elements is characterized, in one way or another, of rules according to which the performers act and according to which a technological environment behaves. In most cases, such rules relate to global design decisions. Thus a rule in the example mentioned in the previous section defines that, at a certain stage of the game, an object falls from the sky each time an avatar uses the jump function. This object generates feedback-like sounds upon impact. This rule relates to a formal section in which this principle applies and co-creates the musical process. This case marks a form of top-down design, as it defines a link between events that plays out regardless of the exact circumstances and details that trigger this function. In general, it can be said that rules only rarely offer ways of shaping the fine details of the musical realization (Ciciliani and Lüneburg 2018, pp. 21–26).[4] Accordingly, when composing with rules, we often find ourselves confronted with the question of how to influence these subtle musical details.[5]

In my compositional work with gaming elements, I have found it increasingly necessary to adopt the performers' experiential perspective rather than searching for a certain sound phenomenon for a selected point in time. The question guiding my compositions is thus not which sound event I want to occur exactly when, but rather: how can I create a situation in which the performers are motivated to perform a certain musical act? Thus I compose situations and stimuli rather than sounds. I try to create a situation that on the one hand corresponds to a precise musical idea, without being able to directly shape the sound events that may occur within said situation. On the other hand, the situation provides a number of affordances, which in their entirety aim to create an interesting and stimulating situation for the performers. Thus motivated, the performers' actions convey the intended musical quality. In the context of the design of game spaces, game theorist Michael Nitsche refers to this phenomenon as "Attractors" or "Perceptual Opportunities" (2008, p. 152). He argues that "spaces evoke narratives because the player is making sense of them in order to engage with them. Through a comprehension of signs and interaction with them, the player generates new meaning" (2008, p. 3).

In the given musical context I argue that in contrast to working with rules, composing situations and stimuli evokes detailed actions on behalf of the performers that can lead to corresponding musical events. Hence, contrary to rule designs, we can here speak of a bottom-up design. This designing of detail can be combined with the designing of rules, though, so the two approaches actually complement each other. Composing rules and stimuli is certainly not a principle restricted to work in 3D spaces. However, because of the virtual presence that performers are able to experience through their avatars, the detailed design of virtual affordances seems particularly appropriate here.

Polyspatiality

The following situation is more or less the classic case in audiovisual concerts: the performers enter the stage, and as the playing starts, a wide-screen video projection appears above the musicians' heads. For the rest of the performance, the audience remains glued to what is happening on the screen and almost forgets the performers present on stage. Situations such as this are not unusual, and there is nothing fundamentally problematic about them—there are many great audiovisual compositions in which such situations are created without compromising the piece's artistic quality in the slightest. Nevertheless, I do ask myself why the visual space of the screen often dominates the events on the real space of the stage so strongly.

When working with 3D environments, where the performance takes place in both physical and virtual space, this particular constellation renders the question even more pressing: how can the relation between physical and virtual space be shaped, a direct link between these two levels established and the real space of the stage be made relevant for the experience as a whole? Is it possible to design a time-variant spatial, topological or architectural counterpoint? In the following I would like to formulate three observations and theses that can serve as a starting point for further analysis.

First, according to my observations, if the projected image is created as the result of interactions between the musicians on stage that the viewers are able to follow, the audience's awareness is less likely to be completely absorbed by the video. This interaction means that the performers are more tangible and thus to a greater degree present as actors in the projection, which links the image more closely and directly to events on stage. In the case of compositions that use gaming elements, there is basically always a more or less direct level of interaction between the performers and the audiovisual setup. It thus seems logical to consciously design the way that the actions are translated between the two levels of projected and physical space. This can mean, for example, that the performers' actions are related directly to the associated behavior of their avatars. In other words, it can mean that the actions and their translations are made transparent and legible.

Second, in my experience, a single projection screen in the performance setup has particularly strong absorbing effect. I describe this setting as a 'cinematic' setup, in the sense that viewers are focused completely on the screen and block out their environment, similarly to a cinema screening. Interestingly, however, using two different projections already breaks the screen's pull. I compare this with an 'installative' situation. Because viewers' visual attention is no longer drawn to a single screen, we are dealing with a setup that is thus not simply distributed across two screens but includes and makes the audience more aware of the whole of the physical space. In other words, while a single screen remains a singular unquestioned attractor, two or more screens articulate a space that also includes the performers and the audience (Petersen 2015, p. 55). I have observed that the events and performers on stage are better integrated into the whole when two or more projections are involved.

Third, a further means of emphasizing the stage more strongly is the time-variant use of light. I have used this several times in projects with a single projection screen, with the light on the stage mirroring color changes in the projection, for example. This made it seem as if the projection were 'spilling over' onto the stage and into the space. Measures such as these are able to reduce the screen's visual exclusivity, drawing attention back to the performance in the physical space and thus creating a more balanced audiovisual experience overall.

Mapping

The following section starts with a somewhat more technical consideration of the way streams of data are generated by the performers' actions and can be used subsequently for interactive audiovisual designs. The performers' movement through an environment via their avatars takes place through the so-called input data they generate. In the case of a normal game controller, this usually happens via a joystick that generates data on movement along the X, Y and Z axes and thus describes the direction of movement. In research on Human-Computer Interaction (HCI), the way that data are allocated to the parameters of a digital system is referred to as 'mapping'. These allocations can be described using the ratio between the input and output signals.

The simplest configuration is one-to-one mapping. Here, a single input signal is allocated to a single parameter. For example, if I move a control and this changes only the volume of the given signal, we are dealing with one-to-one mapping. One-to-many mapping describes when an input signal affects several parameters. For example, we could imagine the same input signal changing not just the volume, but a filter setting, so that the sound becomes brighter as it grows in amplitude. Besides one-to-one and one-to-many we also have many-to-one mapping, which is present for example in wind instruments, where changes in both blowing pressure and finger position can alter the pitch. Accordingly, several input data influence the same musical parameter. Finally, there is also many-to-many mapping, which covers a large number of possible combinations. Another analogy to a traditional instrument serves as an example here: with string instruments, for example, a finely coordinated interaction of bow speed, bow pressure and the bow's position on the string produces a certain timbre that affects both various sound parameters and the volume. What is distinctive here is that the individual input data can no longer be attributed directly to a single change in the sound, but that the complex process of precisely coordinating the parameters with one another leads to changes in the overall sound produced.

In the context of work with 3D environments, I will now describe a two-to-many scenario.[6] Above, as an example of one-to-many mapping I mentioned that an input signal can be allocated to both the volume and filtering of a sound source. This could be expanded as desired, of course. But if the input signal is mapped in the same linear manner to a number of parameters, the result often feels one-dimensional and inflexible, despite this distribution across parameters. It would be preferable for the input signal to be conveyed not linearly, but in dynamically shifting weightings that diverge slightly from one another and shift dynamically depending on context.

In the following examples I am describing a situation where the movement of an avatar in 3D space is controlled by supplying two input signals, one for front and back, and one for left and right, as it is e.g. often the case with computer games. The scenario could just as well be extended to a situation where movement is controlled along all three dimensions, which would not fundamentally alter the described phenomenon. I am therefore confining the example to two dimensions for the sake of simplicity. If we start from the navigation of the avatar via an X and a Y axis and use two input signals, within a 3D environment we are able to derive a far greater number of parameters by measuring the avatar's position in relation to various objects or positions within the 3D environment. Figure 5a shows such a situation: an avatar is moving in the X-Y plane and its distance to five objects or positions in the space is being measured. Accordingly, one single movement is used to define five different data streams. As we are dealing with a situation in which the performers are virtually present through their avatars, the changes in these five data streams takes place in an intuitively comprehensible way. This is relevant if the input data are allocated to parameters including musical options, for example. For this reason, the design of such a mapping can be understood as part of the composition of affordances and stimuli described above.

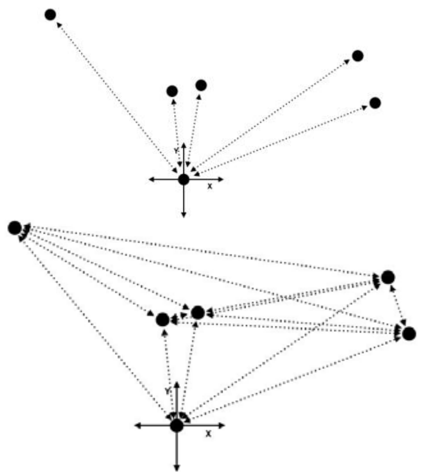

Fig. 5a and 5b. Examples of two-to-many mappings. In 5a, the relations between the avatar's position and five objects in the environment are measured, resulting in a 2 in/5 out scenario; in 5b, the distances between the objects are measured, resulting in a 2 in/15 out scenario.

This distribution of data across parameters is even more extreme if we measure the distance to objects that are themselves moving or that can be moved by interacting with them. If we also measure the relative distances between these objects to generate input data, in the case of five objects we are able to generate no fewer than fifteen signals. This is depicted in figure 5b. It is interesting to note here that not only data describing the avatar's relation to the world are generated, but also data that reflect a state in the environment, in this case the relation of the moveable objects to one another. I once created such a situation in a model where the avatar interacted with a large number of moveable virtual balls, all of which produced a pitch that changed when the avatar touched them. The balls' movement was the result of their interaction with the avatar. The data gained by measuring the distance between the various balls could thus be understood as a lasting effect of the previous action. When implemented, this can anchor the performers more strongly in the virtual environment, as they are able to feel the consequences of their actions.

What is striking about the described scenarios is that the various input data are generated directly from the avatars' movement and interaction, which themselves are steered only through two input channels. Accordingly, the many signals produced still change in an intuitively comprehensible way, rendering them very interesting for audiovisual interactions.

Brief Conclusion

Work with 3D environments offers a range of musical potential and various different creative possibilities: the conscious composition of space and movement, the representation of the performers in the virtual space while being present in the real space at the same time, the use of the 3D environment as both instrument and score, the use of polyspatiality, and not least the interaction and mapping of performers' actions in the virtual environment. This sheds light on many areas of the field that still require further artistic and theoretical enquiry.

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Notes

1 In slightly different versions, this article was previously published in German as

Ciciliani, Marko. “Virtuelle 3D-Umgebungen als Raum für Komposition und Performance,” in *Erkundungen. Gegenwartsmusik als Forschung und Experiment* (Schriften des Instituts für Neue Musik und Musikerziehung Darmstadt, Bd. 59), ed. Jörn-Peter Hiekel. Mainz, 2019, pp. 68–83, and in English as “Virtual 3D Environments as Composition and Performance Spaces,” *Journal of New Music Research* 49:1 (2020), pp. 104–113.

2 Cf. http://gappp.net/english/Ludified-Johnson-Simulation.html

3 During the rehearsal process, the musicians repeatedly used the full view of the 3D landscape reproduced in figure 3 to prepare for the performance of the piece. In this situation, it did indeed function as a score in the sense described above.

4 This is the case particularly when the rules govern the performers' behavior. When rules are applied in algorithmic processes, it is easier to influence the fine details.

5 Rule-based works usually dispense with traditionally notated scores as most of them are conceived as open-form compositions. For this reason, it is normally not possible to notate musical details.

6 The following description is indebted to Rob Hamilton, who employed various forms of ‘few-to-many’ mappings in his work with 3D environments.

Collaborative Creation with Soundcool for Socially Distanced Education

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Soundcool is a flexible, modular computer music software system created for music education. Moreover, Soundcool is an educational approach that embraces collaboration and discovery in which the teacher serves as a mentor for project-based learning. To enable collaboration, Soundcool was designed from the beginning to allow individual modules to be controlled over WiFi using smartphone and tablet apps. This collaborative feature has enabled network-based performance over long distances. In particular, the recent demand for social distancing motivated further explorations to use Soundcool for distance education and to enable young musicians to perform together in a creative way. We describe the educational approach of Soundcool, experience with network performances with children, and future plans for a web-based social-network-inspired collaborative music creation system.

Keywords: Collaborative Creation, Education, Social Distance, COVID.

Soundcool is a free system for collaborative Sound and visual creation that has received several awards and has been invited by the World Science Festival 2019 in New York. See Scarani et al. (2020) and Sastre and Dannenberg (2020) and the references therein for a complete explanation. The Soundcool system offers different modules such as audio and video sources (live audio and video inputs, players, hosts of VST virtual instruments, signal generators), audio and video effects, mixers, video switchers, etc. (See Figure 1). These modules run on personal computers with the possibility for control via Android or iOS smartphones and tablets (see Figure 2), or other devices using the Open Sound Control (OSC) protocol. The system has been used in several education projects in America and in European Erasmus+ education projects, in schools and universities. The connection of the control devices is typically done using a local area network based on a WIFI hub. However, with students and even teachers confined at home because of the COVID-19 situation and online education, we realized that the networking capabilities of Soundcool could be helpful in distance education.

Figure 1. Soundcool 4.0 computer launcher showing Soundcool modules.

In 2016 we developed a system allowing telematic performances with Soundcool through the Internet (Scarani, et al. 2020). We performed a concert called the GlobalNet Orchestra, with participants at Carnegie Mellon University (CMU) and the Universitat Politècnica de València (UPV) (see globalnetorchestra.blogs.upv.es/). However, this system was too complicated to be used generally and quickly, and we have developed a simpler system for online collaborative creation at a distance. We have tested this approach by recording several performances with students and teachers working from their homes, showing that the system can be used even in the more restricted situation of COVID-19 confinement.

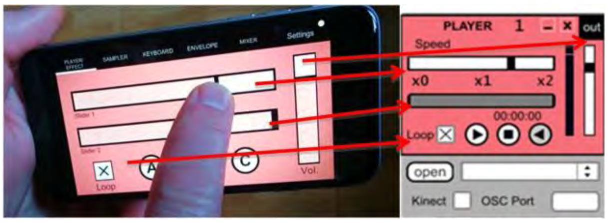

Figure 2. Control of the Soundcool modules with smartphones.

Online collaborative creation and performance

Soundcool was used for a telematic performance between CMU and UPV in 2016. In this performance, our goal was high-quality sound at both performance sites and reliable transmission of parameters in real-time, even at the expense of some added latency.

To deliver high-quality sound, we duplicated the local Soundcool configuration at the remote site. The idea was to deliver the same OSC control messages to a "mirror"

Soundcool server so that, aside from small timing variations, the synthesized sounds would be the same, and we would not need to send high-bandwidth audio over the network. The network would transmit only control information.

Normally, OSC is transmitted over the UDP protocol, which is a “best effort” protocol in which messages may be dropped due to network contention or transmission errors. While this is a minor problem in a local network, packet loss can be disruptive over long distances and many “hops” across multiple networks. To ensure reliable transmission, we created simple software to receive OSC locally, forward the messages to the local Soundcool server over UDP, and forward messages to the remote site using a reliable TCP protocol. Once the messages arrive at the remote site, they are forwarded locally to Soundcool via UDP, making the control system totally transparent to the Soundcool servers, but allowing users to control both servers as one.

As the pandemic isolated teachers and students, we looked for a simple way to use Soundcool. Videoconference systems like Zoom allow a single Soundcool server to send sound to all participants with minimal setup since participants are already connected by videoconference. Participants need only to send OSC messages from smartphones and tablets to the Server to enable real-time collaboration. Aside from packet loss, the main difficulty is that Soundcool network ports are not immediately accessible over the Internet due to standard security precautions in ordinary home routers. However, it is not difficult to reconfigure typical home routers to “open” specific port numbers to receive UDP messages. Only the teacher running Soundcool needs to do this. Once ports are opened, students from anywhere on the Internet can control Soundcool, given the Soundcool program’s Internet IP address and the proper port numbers.

Figure 3. Control of Soundcool in a PC in Valencia from a smartphone in Murcia, Webinar ADMURM (Spain), June 14th, 2020.

A drawback of the UDP protocol, again, is that it does not guarantee that messages are delivered. Tests should be conducted to see if the rate of lost messages is low enough for educational applications. Our first test was done on June 14, 2020 in a Webinar with the Association of Music Teachers of the Murcia Region (ADMURM, Spain) where a Soundcool program running in Valencia was controlled by a teacher and her smartphone in the city of Murcia, at a distance of about 200Km. (youtu.be/B4I3G2YCG-s?t=1736) (See Figure 3.)

Our first telematic performance with the new system featured a collaborative creation with participants from their homes in Madrid and Valencia in Spain, and Pittsburgh in the USA, on June 17. It was a Remix of the famous Kraftwerk's “The Robots,” which was proposed by Jesús Jara, director of the Escuela Municipal de Música y Danza María Dolores Pradera (Madrid, Spain). Participants included his young Sonotronic students, another teacher from the school, Juan Manuel Escalera, and Roger Dannenberg, Stefano Scarani, Saúl Moncho, Manuel Sáez and Jorge Sastre from the Soundcool team. Jesús and the computer with Soundcool were at the school and he shared his screen with all the participants over a Zoom videoconference. The performance was based on triggering samples by the participants, creating a soundtrack for the video, which is taken from the animation “Superman: The Mechanical Monsters” (1941). Participants also controlled the cut-off frequency of a low pass filter, some effects, and mixer levels. The delay and UDP packet loss rate was noticeable but acceptable. See Figure 4 and youtu.be/O8IRLvGZnb8 (English subtitles available).

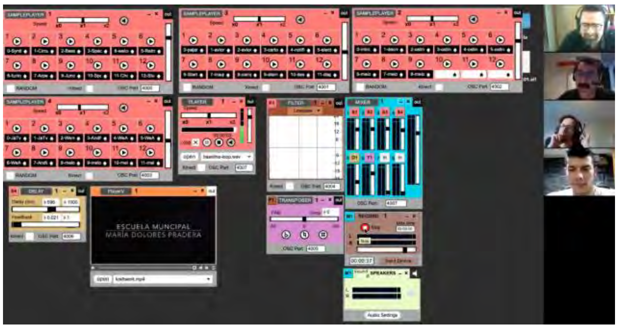

Figure 4. Kraftwerk Remix performance with participants in Madrid and Valencia (Spain) and Pittsburgh (USA), June 17th, 2020.

At the end of July, we offered an online course on collaborative music and audio-visual creation with Soundcool for socially distanced education, and there we challenged the students to make a TV show as the final course work. It consisted of a piece of news and a concert called Crónicas Terrícolas (Earth Chronicles). This time we used Microsoft TEAMS for the course videoconference. (See Figure 5.) One of the participants from Valencia (Spain) controlled a video switcher (top right of Figure 5) to change the video source according to the TV show structure. The TV show video could be seen in full screen, however we preferred that the participants see the TV show in a small window so that they could also see how they controlled the Soundcool modules from their homes. The central computer with Soundcool was at Sastre's office in Valencia. He was the TV show announcer using the live video from a webcam. In the following we explain the work that can be seen at youtu.be/rXQ73PWxzSk (English subtitles available). The piece of news part was triggered by a sound at audio player (P1, Red color) controlled from the Basque Country (Spain) as a sudden alarm sound. It was about a computer virus infecting computers in Catalonia (Spain), the location of the participant who proposed this part. He recorded video previously, which we played at the central Soundcool computer. To make a "virus," the participant controlled a transposing effect applied to the video voice and a participant from Valencia (Spain) controlled video blending with another video (controls are visible at top center, and result is visible at the right of Figure 5). After that, a musical performance took place. Melodies and extended techniques for clarinet and flute had been previously composed and recorded by the participants. The quantity of granular synthesis VST delay effect applied to the music was controlled by Stefano Scarani in Valencia along the piece, and Roger Dannenberg controlled the final mixer levels for the whole TV show with his smartphone connected from Pittsburgh (USA). The piece was improvised in sections cued by Sastre's holding up 1 to 5 fingers:

1) The music started with some improvisations in a virtual instrument (a free vocal type VST) controlled by a participant in Castilla la Mancha (Spain).
2) Then, pentaphonic clarinet melodies were played in Sampleplayer S1 controlled from Andalusia by its composer. They were mixed with the clarinet extended techniques played in Sampleplayer S2 from the Madrid Community by the clarinetist that had recorded them.
3) Then, atonal melodies were played in Sampleplayer S3 from the Valencian Community by its composer, mixed with the flute extended techniques played in Sampleplayer S4 from the Murcia Region by the flutist that had recorded them. Also, after this part there was a sign with both hands for all the participants to stop performing except for the granular synthesis delay, to give variety to the music.
4) Then, again pentaphonic clarinet melodies, but with speed change effects and some more participants performing.
5) We ended with a return to the VST instrument improvisation and a final granular synthesis delay effect.

Finally, the announcer says goodbye. The entire show consisting of music compositions, recordings, etc. was prepared in few days. The UDP packet losses and delays were acceptable for this pedagogic application, showing that the collaborative creation and performance with Soundcool was possible even in a confinement situation.

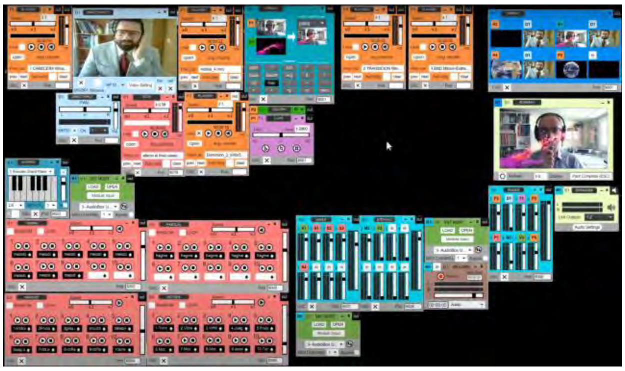

Figure 5. Soundcool patch for the Earth Chronicles show with participants in several cities in Spain and Pittsburgh (USA), July 28th, 2020.

The roll of the teacher in collaborative education

The new teaching paradigm is based on interaction and collaboration between teachers and students. Students locate information when they need it. They have a device in their pocket with which to answer a question at any time. Why then does the teacher have to offer them material that they can find themselves? Collaborative education focuses on the work of the mentor teacher, as a guide to select necessary content, taking into account the students' interests and individual needs. Project learning is essential for this new digital collaborative training. This approach, far from being new, has been known since the middle of the 20th century. The basic levels of Bloom's taxonomy of learning (Bloom, 1956) already anticipate this. Knowledge (theory) and the understanding and the application of these theoretical contents (problem solving and practical sessions) are levels that digital technology already provides without the need for a wise teacher to provide them. However, the complex levels of learning, knowledge analysis and synthesis, and innovation are not offered by technology alone. The teacher must be the center of the dynamization of knowledge and must use the means that his students use daily.

For young people, the Internet, social networks and apps constitute very relevant spaces for socialization, encounter, exchange and knowledge. This is why Soundcool has been considered since its inception as a collaborative learning and creation tool where the teacher has a vital importance in the learning and creation process. As Professor Duart says in his editorial "Internet, Social media and Education," "Teachers have the challenge of being permeable to the changes that occur in the communicative environment and social uses of the Internet. The true transformation is found in the educational dynamics, in the educational process that takes place in the classroom and, today more and more, out of it." If you really want to motivate and reach students, you will have to understand their environment and adapt the teaching to it. And this is the fundamental basis for the development of the Soundcool project, especially as an integrator of STEAM for student learning. Due to this interest, a large part of the project's efforts has focused on generating tutorial materials for teachers so that they can use the tool in the classroom or online as in our last remote connection project. Therefore, several sound, music, audiovisual and multidisciplinary projects are available for teachers in soundcool.org/en/projects/ (see Figure 6), and teacher video tutorials for acoustics and language (Spanish) are available in bit.ly/3lsJibu (see Figure 7). These tutorials have focused on explaining to teachers how to create collaborative training activities with their students using the Soundcool tool, both with all the students in the classroom and with the current social distancing due to the effect of COVID-19.

It has been essential for our project to create not only a tool, which will remain as a mere technological development, but to design a whole model and a teaching methodology that allows teachers to apply this methodology in the classroom. Teachers are encouraged implement technology not as an end but as a means for education and training and to introduce innovation in the classroom through the development of collaborative projects, either in person or in virtual form.

Figure 6. Basic Soundcool projects as radio workshop, soundtracks, producing and recording loops at soundcool.org/en/projects/.

Given the current situation in which we are immersed, students can be reached at any time, but the teacher has to be willing. It makes no sense to close communication with the student outside the classroom, and a collaborative environment must be created that allows this continuous and constant interrelation with all the students, whether in the classroom or in a virtual environment. This is what our tool offers to the teacher: places where the teacher is the center of learning without having to be in the classroom in person and without losing control of the training of their students.

Toward Soundcool as a Social Network

Music is an inherently social process. Soundcool has shifted the focus of electronic music from the individual working alone at a computer to a collaborative design and performance process. As we explore how best to deliver Soundcool conveniently to young users and even non-technical teachers, we have begun a complete re-implementation, moving Soundcool from a Max-based desktop application to a Web Audio application running in the browser. We now have the basic modules of Soundcool running in Web Audio (github.com/ rbdannenberg/soundcool), and our goal is to offer a website where anyone can simply visit a URL in order to use Soundcool.

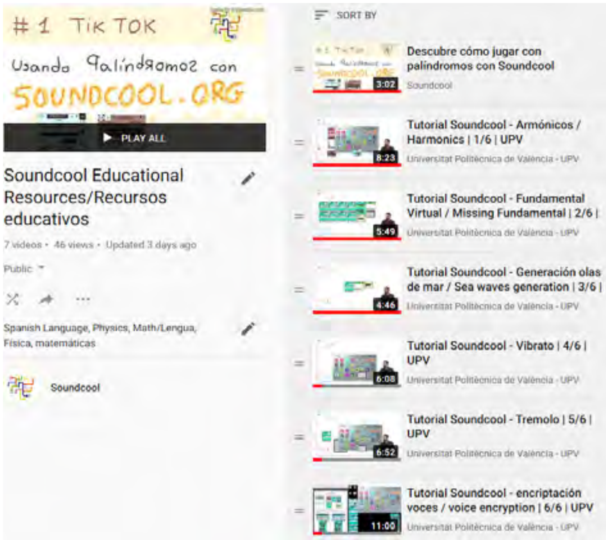

Figure 7. List of Soundcool teacher tutorials.

One advantage of a web-based Soundcool is that users will automatically be interconnected through a shared server. This will enable collaboration through:

- sharing and copying examples, tutorials, and completed works. Students can learn from others or publish their projects to be seen by friends and relatives,
- joint projects can be undertaken by sharing module patches and audio or video samples. Users can compare different versions,
- group performances where each participant downloads and operates a "mirror" of the shared patch. As performers adjust parameters, cue sounds, and make selections, the changes are transmitted through the Soundcool server to all mirrors, and all changes are effected globally.

In this paradigm, it would not be difficult for groups of 2 to 20 play together, even with modest network bandwidth since all audio is generated locally. We expect to make a first release before the end of 2020.

Summary and Conclusions

Soundcool is an easy-to-use but high-quality and very capable system for computer music creation. While intended for young students, Soundcool has found many uses in professional settings due to its combination of flexibility, high-quality sound, and ease of use (see bit.ly/soundcool-pro). Much more than mere technology, Soundcool was designed from the beginning to support collaborative creation, particularly through the simplicity of controlling modules using smartphones, tablets, and WiFi.

The control of Soundcool over WiFi led us to use Soundcool as the basis for collaborative network performances, sending Soundcool audio and screen-sharing to performers using a Zoom videoconference, and using Internet connections from smartphones and tablets to Soundcool for collaborative control by the group.

The collaborations and performances so far have been very encouraging, including a performance with school children from Madrid and with teachers from several cities from Spain. We look forward to more performances as classes are starting again in the fall of 2020.

In the future, we aim to make collaboration and interaction even simpler by creating a web-based version of Soundcool that will be inherently networked and interconnected. This continuation of the Soundcool project will make it even easier to share media, sound design, patches, and real-time collaborative control at a distance.

Soundcool has shown great promise as an innovative approach to music education, a way to expose young students to the possibilities of creative and experimental electronic sound, and a powerful means to enable collaborative creation. Given our current need for social isolation, Soundcool has become a vehicle for bringing young performers together again, by making network performances simple enough for teachers and students without extensive knowledge of networking and computer systems. We look forward to many more possibilities for music and education as we create a Web Audio version of Soundcool.

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Otto Laske and the Visualization of Electro-Acoustic Music: Laske's Visual Music Animations

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Otto Laske (b. 1936), a pioneer of computer music and the founder of "Cognitive Musicology" (which roots in such disciplines as musicology, philosophy, computer science, psychology, linguistics, semiotics, and sociology), combined his research with his artistic activities: initially composition and writing of poetry, later also digital art. This paper provides some biographical, artistic, and research background of Laske's theories to explain his electro-acoustic music (1966-2009) and his artistic fulfillment in the visualization of his electro-acoustic music (2011-2012). For these animations, individual frames became the 'negatives', on which he bases his work in the visual arts. This art is musically inspired throughout, with a focus on flow, tension, conflict, and movement. In his visualizations, animation 'objects' carry visual images or even a sequence of images, and while the images move against and through each other, their colors, shapes, and textures follow the flow of the music. Laske treats an animation still as the visualization of a set of pixel-level parameters that define the shapes, colors, textures, and dynamic characteristics of an image. Working with Cinema 4D, Studio Artist, and Photoshop, Laske's work is highly creative. Several of Laske's Visualizations are being explored and holistically viewed within the framework of his lifework.

Keywords: Otto Laske, electro-acoustic music, visualizations, visual arts.

From the 1970s through the 1990s, Otto Laske was one of the leading scholars in the area of Artificial Intelligence and Music. He is the founder of "Cognitive Musicology," which roots in such disciplines as musicology, philosophy, computer science, psychology, linguistics, semiotics, and sociology. Besides his research in and across these disciplines, Laske combined his research with his artistic activities: composition, especially computer music, and writing of poetry. Such interdisciplinary and inter-artistic thinking was necessary to create the Cognitive Musicology, of which the main focus is on creative processes. In the late 1990s, Laske pursued a Psy.D. in clinical psychology, and in his artistic work focused more and more on visual arts, creating a series of visual animations with computer music.

Laske's research cannot be separated from his various activities throughout his career and from his artistic activities. Therefore, this paper is in two parts: it will provide some biographical notes and then focus on Laske's creative activities, especially the visualization of electro-acoustic music.

Biographical Notes on Otto Laske

Otto Ernst Laske was born on April 23rd, 1936, in Oels (Olesnica), Silesia. Together with his mother and sister, he escaped from the oncoming Soviet army in 1945, which brought him to Lilienthal, near Bremen (Germany), the city in which his mother was born. There, he soon started playing the piano. At age 11, he met his father, who had been a prisoner of war in the Soviet Union; still in a war trauma, Laske tried himself in writing poetry from age 13 on. Although he temporarily interrupted his piano studies and, thus, his musical activities, he never lost the contact to the music, as his family was very music-loving.

After a social-science diploma at the business high school in Bremen (1955) and after one year of administrative work, Laske started studying business administration in Göttingen in 1956. There, stimulated by the Sociological Institute, he started research on sociology. This interest in sociology brought him to the Goethe University in Frankfurt / Main and the Institute for Social Research (Institut für Sozialforschung) with Max Horkheimer and Theodor W. Adorno. While he abandoned his business studies, his sociological interest led him to studying philosophy, which he started (after a second, classical high school diploma) in 1958. In addition, he studied musicology from 1960 on (with professors Helmuth Osthoff, Friedrich Gennrich, and Lothar Hoffmann-Erbrecht) as well as English and American Language and Literature from 1964 on. After intensive studies of Greek philosophy, especially supported by Bruno Liebrucks, Laske wrote his dissertation under the supervision of Theodor W. Adorno on the dialectics of Plato and the early Hegel, which he completed in 1966.

During his academic studies, specifically from 1961 on, Laske continued his music-practical studies, as he picked up composition and studied Hindemth's *Untersuchung im Tonsatz*. From 1963 to 1966, Laske studied composition primarily with Konrad Lechner: first, at the Frankfurt Musikhochschule and later at the Academy of Music in Darmstadt. Besides his studies with Lechner, who specifically continued the tradition of Guillaume de Machaut and Anton Webern, the Darmstadt Summer Courses were very stimulating for Laske's musical developments, where he met composers such as Stockhausen, Ligeti, Boulez, and Babbitt. In Darmstadt, he also met Gottfried Michael Koenig in 1964, which became most crucial for the development of Laske's composition theory and Cognitive Musicology.

After completing his dissertation, Laske was a Fulbright Scholar from 1966 to 1968 at the New England Conservatory in Boston (USA), where he graduated with a Master of Music degree in composition. He then gained teaching positions, each for one year, as visiting professor of philosophy in Ontario (Canada) and as visiting professor of musicology (specifically the music of the Middle Ages, the Renaissance, and the Baroque) at McGill University in Montreal (Canada). Invited by Koenig, Laske taught and studied at the Institute of Sonology in Utrecht (Netherlands) from 1970 to 1975. During the time period from 1971 to 1974, he was holding a fellowship from the Deutsche Forschungsgemeinschaft (German Research Foundation) for the project "The Logical Structure of a Generative Grammar of Music." Besides his collaborations with Koenig and Barry Truax, the training in a classical electronic studio became very important for Laske. Here, influenced by informal studies of computer science (1972-1974), he developed the foundations for his Cognitive Musicology.

After two additional years of studies (1975-1977) in psychology and computer science as a post-doctoral fellow at Carnegie Mellon University in Pittsburgh, Pennsylvania, and after completing a year as guest professor at the University of Illinois in Urbana (1978-1979), Otto Laske's research was extensively focused on Artificial Intelligence. He worked from 1980 through 1985 as software engineer and from 1986 through 1991 – especially in Switzerland, Germany, and The Netherlands – as a consultant for the development of expert systems. In addition, he was a guest professor of computer science for one year at Boston College in Chestnut Hill, Massachusetts. Already since 1984, he was more interested in the process, through which one gathers expert knowledge (to eventually create expert systems with that knowledge), than in programming.

From 1981 through 1991, Laske was – initially with Curtis Roads – artistic director of the New England Computer Music Association (NEWCOMP). During this time, he organized 65 concerts for mixed media and taught courses on computer-assisted composition in Stuttgart (1981), Darmstadt (1981), Boston (1981-1984) and Karlsruhe (1988/89). In 1992, he turned towards developmental and clinical psychology (Harvard University), to gain the theoretical basis for a theory of coaching. From 1996 to 1999, Laske studied clinical psychology at the Massachusetts School of Professional Psychology and received a Doctor of Psychology (Psy.D.) with his dissertation on "Transformative Effects of Coaching on Executives' Professional Agenda" (1999). He founded the consulting form Laske and Associates LLC (2000), and later the Interdevelopmental Institute (2004) – an institute for advanced coaching and cadre education, focusing on dialectical and thinking and transforming organizational structures.

As an artist, Laske has an extensive compositional work, a large output of poetry, and he dedicated himself in recent years to visual arts. Much of his compositional work informed his research on creative processes in music. A Festschrift was published in recognition of his scholarly and compositional work (Tabor 1999).

Laske's Compositional Work

Laske's manifold scholarly activities and, thus, the development of his Cognitive Musicology, are hard to separate from his artistic work (composition as well as poetry), because composition theory is in the center of both areas.

Between 1964 and 1970, Otto Laske composed – under the influence of his teacher Konrad Lechner ("micro-counterpoint") and of Darmstadt (Stockhausen) and Renato de Grandis – only instrumental or vocal music without the computer. However, already his Two Piano Pieces (1967-69) were composed "top down," as later with Koenig's computer program "Project 1." Laske met Koenig in 1964 in Darmstadt, and most stimulating was a lecture by Koenig on composing with computers, which contained the main principles of what later became "Project 1." This program for interpretative composition is the one program to this day that is primarily used by Laske. During the early 1970s, however, Koenig's programs had little practical, but strong theoretical influence on Laske. Influences regarding counterpoint came from Avram David (Boston), while Robert Cogan (Boston) developed Laske's understanding of musical form. Overall, however, Laske remained autodidact.

Laske's music of the 1970s was influenced by the classical electronic studio: electroacoustic music was dominating. He mainly used Barry Truax' POD. Many other works were only influenced by the (thinking of the) way in which computer programs work (for instance, Quatre Fascinants for 3 Altos and 3 Tenors, with lyrics by Renee Char, 1971), but only Perturbations for flute, clarinet, violin, violoncello, piano, and 2 percussionists (1979) was completely composed using "Project 1." In the 1980s, Laske wrote music for tape as well as instrumental and vocal compositions, whereby "Project 1" was the synthetic program for all compositions. An "electronic turn" came about with Furies and Voices for loudspeakers (1989-90) – for which he used PODX (granular synthesis) –, since melodic-rhythmic configurations of the 1980s tape compositions were replaced by a focus on density and sound color. This development continued in the 1990s, in which compositions for tape dominate, which are based on his own poetry: for instance, Treelink (1992) or Twin Sister (1995). Here, for the first time, Laske composed – with the help of Kyma – "bottom up," starting with the sound material. After the Third String Quartet (1992-96) and his Organ Piece (1998-99), Laske 'returned' to "Project 1" with *Trilogy* for tape (Echo des Himmels, Erwachen, Ganymed; 1999-2001). And although Laske used Cmask after 2001, he once more 'returned' to "Project 1" with his Symphony No. 2 (2003-2004).

Laske's instrumental works often show differentiated "soundcolor-counterpoint," which is also effective with vocal parts, while a-cappella works frequently show harmonic experiments. In tape compositions of the 1970s and 1990s, a primary interest in sound is dominating, while the tape compositions of the 1980s are rather contrapuntal. For Laske, music is primarily a lyrical expression, to which epic and dramatic elements are subordinate. His music is, it its variety, a personal expression via new, technical means. It strives for expression through constructions that are created rich of relations to sound and meter.

Otto Laske discovered a substantial change within composers who work with computers: a change from model-based to rule-based thinking, despite the motivation within the developmental tendency of musical thinking to return to model-based thinking. (See Laske 1989d, 3.) While in traditional compositional practice, existing music is the basis – the model – of composing, there is a new category – besides "existing music" – in composing with computers: "possible music". The latter is music "that can be envisioned by a musical expert on the basis of an abstract set of rules, on which a computer program is based" (ibid.). These abstract sets of rules may, hereby, lead to new musical forms and means of expression.

Laske distinguishes three ways of composing with computers: score synthesis, sound synthesis, and musique concrete. (See Laske 1994.) While computers are used as the sound source for sound synthesis, and as the sound-transforming instrument for musique concrete, score data – such as pitch, duration, dynamics, etc. – are, in score synthesis, being generated ("synthesized"), via a computer program, which are then – as a result of interpretation – notated, or translated into data for an orchestral language. Thus, Laske uses score synthesis for notated music as well as for tape compositions, which are based on sound synthesis (instead of on sound transformations). Hereby, the most important step is the interpretation of numerical data that could lead to totally different results. Laske uses score synthesis via Koenig's programs "Project 1" and "Project 2." Since score-based music is a special kind of music within the electronic realm, it is nowadays often called "score based sampling" and associated with Laske's name.

Almost all of Laske's instrumental and vocal works composed after 1971 are created using score synthesis, while all compositions for tape of the 1980s are based on "top down score synthesis," using "Project 1." Laske's compositions are, to equal portions, music for loudspeakers and instrumental chamber music (including music for solo instruments). Several pieces for loudspeaker set his own poetry to music; he does not use lyrics by other poets for his electronic compositions. In addition, there are numerous pieces for solo voice and chamber ensemble or music a cappella, of which six are based on his own poetry.

For Otto Laske, composing is closely related to his scholarly activities: "But I'm not interested in programs or machines that turn out compositions. Rather, what has always interested me are machine that allow and invite reflection about the compositional process and that simultaneously lead to a compositional product." (Laske, quoted in Schüler 1999, 149.) In this sense, Laske's artistic activity is a part of his scholarly research. However, since 1990 the emphasis on theoretical aspects of computer programs decreased in favor of their use as the basis for compositional thinking.

Otto Laske's Visual Music Animations

All of Laske's visual art and compositions, and some of his poetry, show the interrelationship between himself and "the computer as the artist's alter ego" (Laske 1990). In his artistic late-work, Laske transferred his experiences in shaping artistic materials in poetry and music to visual arts. (See Laske 2016a.) Throughout his career, Laske always saw new technologies as a gateway for new art. And so in

2009, Laske started a series of three visual music animations "to discover that animation stills are a potent source of both digital photography and digital painting. In light of the importance of music in my life, all of my visual work is 'frozen music' showing the inner dynamics of shape, color, texture, and line." (Ibid.) Among Laske's visual art, his visual music animations most closely represent his focus on artistic processes. Not only is he crossing painting, drawing, photography, collage, and animation, but the animation processes are in the center of visualizing Laske's computer music, because all of his visual music animations are based on his own electronic music as well as his own poetry. The musical syntax dictates the animation processes, and the colors are a visualization of the orchestration and, thus, sound colors. Sequences of images outline the musical form. In Laske's visual music animations that use poetry, however, the poetic meaning dominates and dictates images and sound (just like the lyrics dictate the sound in Laske's compositions with lyrics); in those lyrics-based visualizations, the images interpret the poetry. (Ibid.) Generally speaking, however, the traditional artistic genres are so fluidly married with each other that Laske's visual music animations can and should be seen as a new artistic genre itself.

Each of the three visual music animations shall be briefly discussed here. As his first animation, Coves was completed in 2011 and based on parts of Laske's 2009 electronic music "Being and Nothingness", the title of which refers to Satre's existentialist philosophy. The title of Coves, which can be viewed at https://vimeo.com/29217893, refers to pictures Laske took of several Cape Ann coves near Gloucester, MA, where Laske has been residing since 2010. These pictures were taken at Lanesville, Pigeon Cove, and Halibut Point (the most northern part of Cape Ann) in Massachusetts. A cove is a small type of bay or coastal inlet, often with narrow entrances and oval in shape. Dedicated to Dennis H. Miller (an animator and composer from the suburbs of Boston), Laske's Coves reflects on the storms that helped shaping coves as well as the land's dependency on the sea, with both its threats as well as potentials (Laske 2016b). Synthesized, stark, melodic elements represent Nothingness, which provokes self-realization, or Being. Laske produced the music with Project One and Cmask as well as the Capybara sound engine. The first part of the 3-part, 8-minute visual music animation Coves represents moving forces that gradually overlay and move against each other. The second part "highlights the internal conflict of these moving forces, physical and psychological" (Laske 2011), while the third part continues the conflict, but calms down toward the end. Visually, sea landscapes are overlayed with rocks, waves, and the moving sky throughout Coves, set to a variety of sound mixtures.

Laske's 14-minute visual music animation TreeLink from 2012 (which can be viewed at https://vimeo.com/46947568) is based on Laske's reading of his own poetry with the same title, written in 1979, and on his electronic composition TreeLink from 1992. The lyrics are as follows (Laske 2016b):

> Evening light is weighing down
> on the playground oaks and maples
> early this wintry day.
>
> Here, in the snow-soft meadow,
> I have stood before, happier,
> not noticing the weight
> in the trees, when the sun sank
> to close the afternoon.
>
> The trees have aged.
>
> I suddenly know
> they were always aching
> under the heavy light.
>
> Afternoon hides below the grass,
> a raven descends, and the wind
> takes years off the branches,
> shifting them to my shoulders.
>
> I return weighed down,
> more certain,
> more luminous.

In his electronic composition TreeLink, text- / language-fragments are embodied by sounds, partially synthesized (via Capybara and its Kyma language) and partially based on the (modified) sounds of the reading itself. With his visual music animation, Laske added a third artistic layer (besides lyrics and electronic music) by creating collages based on images by multi-media artist Michael Rhoades, by composer and visual artist Sylvia Pengilly, and by glass artist Crispian Heath. TreeLink addresses the topic of aging in five parts. Laske states about his used of his collages: "My use of collages in this animation is intentionally 'painterly'. The movement of the images is closely allied with the flow of sound energy, and it is this alignment that, for me, is a must in 'visual music'." (Laske 2016b.) Trees play a central role in the imagery, as the poetry refers to a wooded area near Laske's former residence in Needham, Massachusetts.

Dedicated to Laske's wife Nadine Boughton, Farewell to Los Angeles (2012), which can be viewed at https://vimeo.com/37404596, is based on Laske's (own) reading of the poetry with the same title, written in 1979. (The relatively lengthy poetry can be found at Laske's website at http://ottolaske.com/animations.html.) The poetry centers around love and departure. The music used was taken from several of Laske's electronic music compositions: "Message to the Messiah", "In Memory", and "Trilogy" (Erwachen and Ganymed). "Message to the Messiah" (1978), which was composed at the Electronic Studio of the University of Illinois, was the first piece in the Needham Series and is Laske's only 'synthesizer music': based on a recorded improvisation on a Buchla Synthesizer with naturesque imagery (especially of the sea and of birds). "Memory" from 1988 is the fifth piece in Laske's Needham Series, which was composed to celebrate his mother's life. Originally a traditional score, composed with predefined progression rules, "Memory" was orchestrated with the polyphonic digital synthesizer DMX-1000. Last but not least, Laske used two pieces from "Trilogie" (2001), Erwachen and Ganymed, in which tone colors / sonic qualities are the central focus. Among all three of Laske's visual music animations, Farewell to Los Angeles contains the clearest form of poetry reading and imagery. As "video poetry", the collages of both realistic and abstract images follow, with their dialectical movements, the stanzas of the poem, supported by the structure of the music, to bring out the poetry in its fullest, like a "Gesamtkunstwerk".

For all of Laske's animations, individual frames became the 'negatives', on which he bases his work in the visual arts. This art is musically inspired throughout, with a focus on flow, tension, conflict, and movement. In his visualizations, animation 'objects' carry visual images or even a sequence of images, and while the images move against and through each other, their colors, shapes, and textures follow the flow of the music. Laske treats an animation still as the visualization of a set of pixel-level parameters that define the shapes, colors, textures, and dynamic characteristics of an image. Working with Cinema 4D, Studio Artist, and Photoshop, Laske's work is highly creative.

Final Remarks

Laske's visual music animations best represent his entire artistic and scholarly work. Musical competence and performance (activity) as well as musical artifacts are to be examined in their polarity, which means that the examination of musical artifacts has to occur not only in themselves, but also with regards to its underlying competence and performance. Music is a series of tasks, of which cognitive structure and processes are to be explored. To have developed such a methodology is the result of Laske's research in linguistics, but especially in psychology, computer science, and Artificial Intelligence. Music is understood as a cognitive achievement, which requires – in order to understand it – a structural as well as procedural analysis of tasks. Thus, dialectical thinking with its distinction between 'structure' and 'process' as well as the emphasis on work in real time are central categories in Laske's work, and his visual music animations exemplify them in the artistically broadest way.

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Musical Motion at Different Scales: Creative Analysis and Resynthesis of Musical Contour Spectra

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In the context of music technology, Fourier analysis is generally applied directly to sampled sound waves, with the goal of revealing timbral information about the sound or sounds in question. By contrast, this paper presents a software tool (“Spectral Musical Contour Explorer") for applying Fourier analysis to more abstract musical time series; for instance, one can analyze a melody as a time series of pitches, or a recording as a time series of RMS volume measurements. Such analyses can uncover salient and musically meaningful periodicities within the structure of musical works. Moreover, the different time scales of these periodicities reflect the multilevel nature of musical structure (e.g. meter, phrase, form). Finally, the software can be used creatively to resynthesize new pitch and volume contours from a hand-selected portion of the analysed spectrum. In particular, we discuss several compositions by the author that use this process to generate novel musical material from melodic and dynamic contours found in canonical repertoire.

Keywords: Fourier Analysis, Resynthesis, Contour, Composition, Software, Form, Melody.

The mathematical tool of Fourier Analysis is used in a wide range of fields and contexts, and can be applied both to time-series data, or to data distributed over another (e.g. spatial) dimension. In music and audio analysis, the most typical use of Fourier Analysis is the application of a Discrete Fourier Transform (DFT)—most typically a Fast Fourier Transform (FFT)—to a sequence of audio samples. This is a powerful tool for timbral analysis, filtering, synthesis, efficient convolution reverb, and many other musical applications (Smith, 2007).

Aside from forming the basis of many of the software tools that musicians use today, this application of Fourier Analysis played a central role in aesthetic movements within the field of music composition, in particular the advent of so-called *spectralist* approaches in the 1970’s (Moscovich, 1997). Within the field of music theory, there has recently been a resurgence of interest in a different usage of Fourier Analysis, namely its application to abstract musical structures, such as pitch-class distributions (Amiot, 2017; Quinn, 2007). Here, rather than samples evenly spaced in time, the analysis focuses on samples within circular pitch-class space, an ‘outside-time’ musical structure, to use the language of composer Iannis Xenakis (1992).

This paper considers a third category of usage: the application of Fourier Analysis to ‘in-time’ structures that represent changes in abstract musical parameters, such as pitch and volume. (These fluctuations will be termed ‘musical contours’ throughout this paper.) Such an approach has been considered sporadically, for example by Nettheim (1992) and Voss (1978), and a similar analysis and resynthesis approach using wavelet analysis has been taken by Kussmaul (1991), but it has yet to receive widespread recognition.

This paper both revives this line of research and presents a newly developed piece of software—entitled “Spectral Musical Contour Explorer”—for creatively analyzing and resynthesizing novel melodies and dynamic contours using this approach. Finally, the creative results of this exploration are discussed, in the form of several of my own compositions.

Non-technical Introduction to Fourier Analysis

For the sake of readers coming from a more musical than mathematical background, we begin with a non-technical introduction to the tool of Fourier Analysis, as applied to a recorded waveform. Fourier Analysis is what we use when we talk about the spectrum of a complex sound; for instance, when we say that a clarinet tone has only odd harmonics, or that the first harmonic of a trumpet is stronger than its fundamental, we are referring to the results of Fourier analysis. The central idea is that a complicated motion—in this case, the motion of an air particle under the influence of a trumpet or clarinet—can be

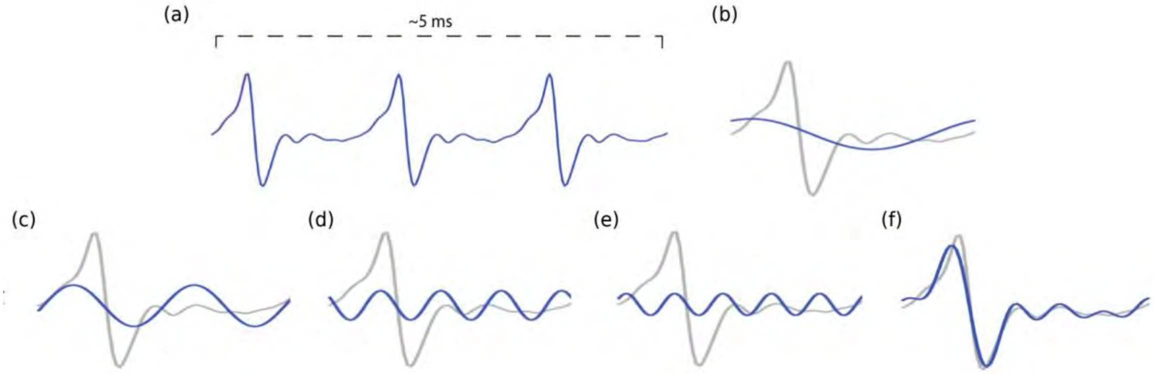

Figure 1. (a) Short excerpt from a trumpet waveform showing a repeated fluctuation in air pressure. (b)-(e) One period of that fluctuation (light gray), with the 1st (fundamental), 2nd, 4th, and 5th harmonics isolated, respectively (blue). (f) The recombination of those harmonics (blue) as compared with the original waveform (light gray).

decomposed into a superimposition of very simple motions at different speeds.

Figure 1a shows the waveform (i.e. graph of the fluctuation in air pressure) of several periods of a trumpet tone. The unique shape of the waveform creates the trumpet's sonic signature. Note that these fluctuations happen very quickly; the shape repeats three times over the course of 5ms, which translates to 600 oscillations per second (Hz), or roughly a concert D5.

What Fourier synthesis does is break down this complex signature into a sum of sine waves at integer multiples of the 600Hz frequency of the complex pattern. Thus, for a 600Hz trumpet tone, we have components at 600Hz, 1200Hz, 1800Hz, 2400Hz, etc., which we would term the 1st, 2nd, 3rd, and 4th *harmonics* or *partials*. Each partial has its own weighting (*amplitude*) and alignment (*phase*).

We can see what this looks like in Figures 1b-e, which show the 1st, 2nd, 4th, and 5th partials of the trumpet waveform respectively (the original waveform is shown in gray for reference). The first partial completes one cycle for every cycle of the complex trumpet tone; thus it, like the trumpet tone, is oscillating at 600Hz. The second partial completes two cycles for every cycle of the trumpet tone; thus it is oscillating at 1200Hz. Of the four partials shown, notice that the second partial is the strongest, and that the phase of each of the sine waves is such that its peaks and valleys align well with the peaks and valleys of the complex waveform.

Figure 1f shows the sum of these sine waves, which very nearly reproduces the original trumpet waveform. In fact, there is no physical or acoustical difference between the simultaneous sounding of the sine waves in 1b-e and the sound of their sum in 1f. If we wished to reproduce the original trumpet wave with perfect fidelity, we would simply need to include the remaining relatively weak higher harmonics.

It turns out that there is only one way to break a complex wave shape into a sum of sine waves like this, and we call this unique combination of harmonics with different amplitudes and phases a *spectrum*. Thus, when we say that the sound of a trumpet has a strong second harmonic, we mean that the effect of the complex pressure wave produced by a trumpet is identical to the effect of a very specific combination of sine waves added together, and that the second of these sine waves is the strongest.

Musical Countour Spectra

In a musical context, the term *spectrum* is very readily associated with *timbre* and with the direct application of Fourier Analysis to a recorded waveform. Indeed, many canonical examples of the "Spectral" music that emerged in the 1970's (e.g. Gerard Grisey's Les Espaces Acoustiques) are based specifically on transcribing the results of such an analysis to music notation (Féron, 2011).

However, because Fourier analysis is an abstract mathematical tool, it can be just as easily used to analyze the variation in any other musical parameter, at any time scale. For instance, the pitch of a melody can be seen as a time-varying property, operating on the scale of seconds rather than milliseconds. Such analysis, combined with creative resynthesis, can be a source of novel musical material, as we shall see.

Figure 2 depicts the melody of "Pop Goes the Weasel," first in traditional music notation, and then as a time-varying pitch contour. By depicting the pitch of the melody in this way, we see that it is, mathematically, just like the trumpet waveform from before. The only difference is that this wave represents the motion of an abstract musical parameter, rather than of air pressure directly, and that the variation is on the scale of seconds rather than milliseconds.

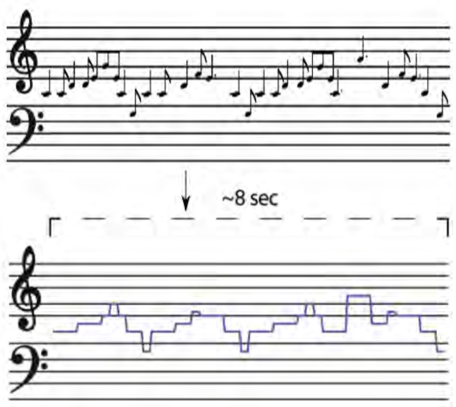

Figure 2. The melody "Pop Goes the Weasel," first in traditional music notation, and then reinterpreted as a time-varying pitch contour.

There is, therefore, no reason we cannot apply Fourier analysis to this pitch contour, just like we did with the trumpet waveform. As with the trumpet, these oscillations operate at 1x, 2x, 3x, etc. the frequency of the melody itself[1], and each of these 'partials' has its own amplitude and phase, with some partials being especially influential.

Figure 3 shows some of the lower partials. The first partial (Figure 3a) is not particularly strong, but its phase is nevertheless aligned so that the peak coincides with the highest note (A4) of the melody. The same can be said of the second partial (Figure 3b). The strongest component is the fourth partial, which completes four full cycles over the course of the melody (Figure 3c). Why is this?

The reason is that the melody itself is in four parts, and each of its first three phrases follows the same pattern of low then high. The final phrase, starting on the A, the highest note in the melody, is somewhat of an exception. In order to compensate, the first and second partials are aligned so as to peak at this exact moment, as is the eighth partial shown in Figure 3d. The eighth partial also helps to create the more local peaks at G4 in the first and third phrases.

Adding together the partials depicted in Figure 3a-d, we arrive at the contour shown in Figure 4a, which tracks the motion of the melody fairly faithfully, albeit a little too smoothly. In order to achieve the flat pitch plateaus that our western ears have come to expect, we need to include more rapid fluctuations like the 20th partial (Figure 3e) to help flatten out the peaks of the slower sine waves (Figure 4b). As with the trumpet waveform, by including enough partials we can reproduce the original melodic contour with perfect fidelity.

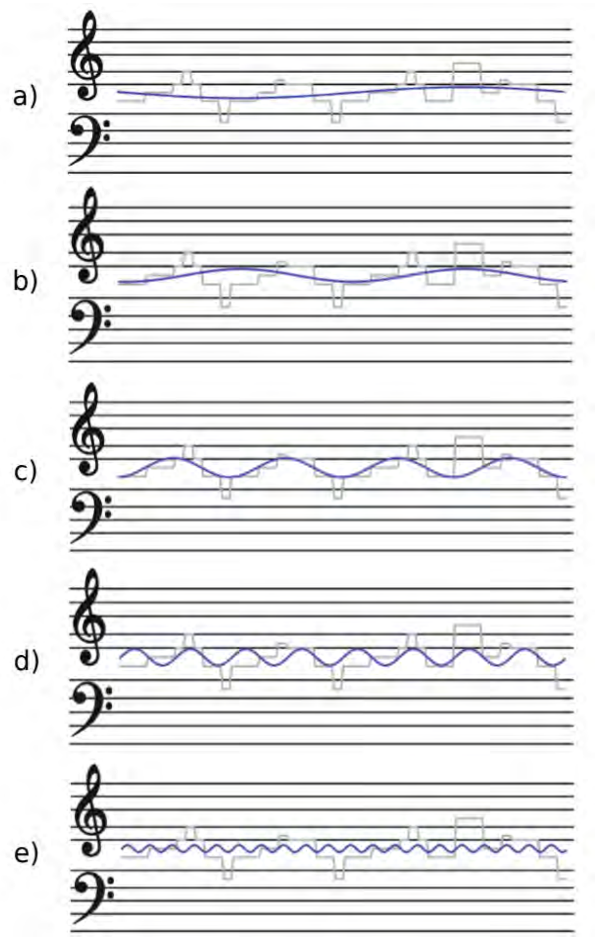

Figure 3. The (a) 1st/Fundamental, (b) 2nd, (c) 4th, (d) 8th, and (e) 20th harmonics of harmonics of the pitch contour of the melody "Pop Goes the Weasel" (blue), superimposed on the original contour (light gray).

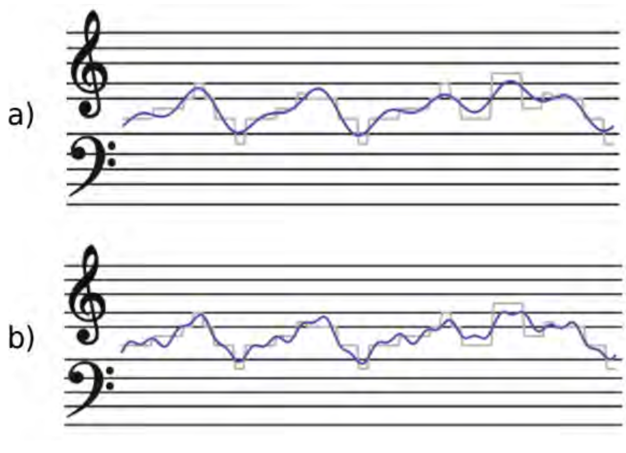

Figure 4. (a) The sum of partials 1, 2, 4, and 8, producing a passable approximation of the melodic contour. (b) Sum of partials 1, 2, 4, 8, and 20, showing that partial 20 helps to flatten out some of the peaks into plateaus.

Figure 5. Comparison of (a) the opening melody from the second movement of Beethoven's Pathétique and (b) a corresponding passage in Adagio Cantabile. (c) is an excerpt from towards the end of the work.

A Mathematical Schenkerian Analysis

The above should give some indication of the potential for using this kind of Fourier Analysis as an analytical tool. Among the magnitudes and phases of the various partials was valueable information about the structure of the melody, from its overall shape (1^{st} and 2^{nd} partials), to its phrases (4th partial), to hints of its motivic and rhythmic structure (8th partial). Those familiar with the theories of Heinrich Schenker may note a certain kinship here, in that both Schenkerian analysis and this application of Fourier Analysis represent a hierarchical view of musical structure. (In Schenkerian analysis, this hierarchy is represented by a range of interrelated structural levels, from background (*Ursatz*), to middleground, to foreground (Cadwallader & Gagné, 2007).)

From an analytical point of view, the process described above may provide a valuable complement to the process of Schenkerian Analysis, with the former valued for its objectivity, and the latter for its subjectivity.

A Tool for Creative Resynthesis

The illustrations in Figures 2-4 were produced using a tool that I created for analysis and resynthesis of musical contour spectra, called "Spectral Musical Contour Explorer." This program was created in Python, using PyQt5 as the underlying GUI framework, and using an embedded ChucK (Wang & Cook, 2004) binary for rudimentary sound synthesis. A more complete screenshot of the program is shown in Figure 5.

To begin with, the user is allowed to load either a MIDI file or a WAV file. In the case of a MIDI file, the average pitch of all active MIDI notes over time is plotted against a grand staff[2], while in the case of a WAV file, a plot of the variation in RMS volume over time is displayed. When inputting a MIDI file, the user is prompted for a length, in quarter notes, to assign to each sample; when inputting a WAV file, the user is prompted for the desired window size for calculating the RMS.

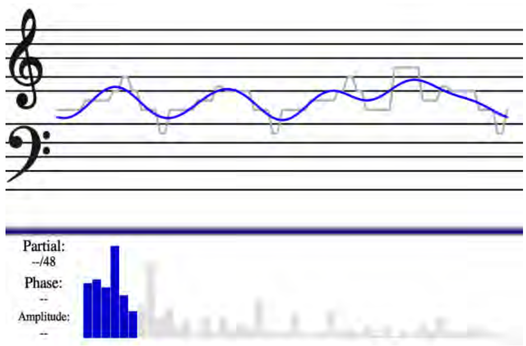

Figure 6. Screenshot from "Spectral Musical Contour Explorer." The bottom half of the screen shows the contour spectrum of the melody, with active partials in blue and inactive partials in gray. The top part of the screen plots both the original melody (in gray) and the reconstructed melody (in blue).

By mousing over the partials of the spectrum in the bottom half of the screen, additional information about phase and amplitude can be viewed, and the user can then click any these partials to toggle them on and on or off. In this way, any partial spectral reconstruction of the contour can be achieved. Finally, the samples of the reconstructed contour can be exported in the form of a text file, so that they can be used in a composition, or for further analysis.

Creative Results

Adagio Cantabile

The first piece in which I made use of this technique was *Adagio Cantabile*, for oboe and guitar. Using as source material the main theme of the second movement of Beethoven's *Sonata Pathetique, Op. 13*, I performed Fourier analysis and resynthesis on both pitch and rhythm independently (encoding rhythm as a sequence of note length samples[3]). A happy accident occurred in this process: since I was treating pitch values as continuous, rather than discrete, I ended up with microtonal inflections in the resulting resynthesis. This ended up becoming a central aspect of the oboe part.

After exploring the space of possible reconstructions, both in pitch contour and rhythm, I ended up with a collection of short melodic snippets, which I ultimately assembled using pencil and paper. Figure 6 compares the opening melody of the Beethoven (a) with a two excerpts from *Adagio Cantabile* featuring a partial reconstruction of the melody. In (b), the overall contour of the melody has been removed, leaving only the slight microtonal deviations. In (c), taken from near the end of the work, it is the local ornamentation—the higher frequency information—that has been removed, leaving a melodic line that sweeps gradually up and down. In this latter case, I allowed myself considerable flexibility in choice of accidentals, letting my ear guide such decisions intuitively.

Unraveled

The second piece in which I used this technique was *Unraveled,* for Percussion Quartet and Impossible Electronic Orchestra. The title gives a hint as to the source material: the famous melody from Ravel's Bolero. I used the software described here to analyse and resynthesize the melody in various degrees of recognisability, and then had these reconstructions performed by an "Impossible Orchestra," consisting of pitch-bent samples of orchestral instruments.

As with *Adagio Cantabile*, then, the contour in question is a melodic pitch contour. An added wrinkle in this case, however, is that rolls in percussion parts are used to emphasize the individual partials of the melodic contour, with many of these rolls superimposed on one another at a given time. Thus, though the fission process of Fourier analysis, the monophonic melody gives rise to a heterophonic accompaniment, one which emphasizes details within the melody itself.

Anamnesis

The third (and most recent) work that I composed using spectral analysis and resynthesis of musical contours is *Anamnesis* for Chamber Orchestra. Anamnesis differs from *Adagio Cantabile* and *Unraveled* in that the musical contour being analysed was a dynamic contour, rather than a pitch contour. Here, again, I used a famous work as the source material for analysis: the *Allegretto* from Beethoven's *Symphony No. 7*.

Figure 7a shows a screenshot (from the program *Audacity*) of the recording by Carlos Kleiber and the Vienna Philharmonic Orchestra. Figure 7b shows this same recording, as loaded into "Spectral Musical Contour Explorer": a dynamic contour has been created by calculating RMS values for every half-second of audio, effectively resulting in a unipolar version of what we see in Audacity. Figures 7c, d, and e show three examples of strong periodicities found in the dynamic contour through analysis. Notice, for instance, how the second harmonic depicted in Figure 7c highlights the two main peaks of intensity within the movement.

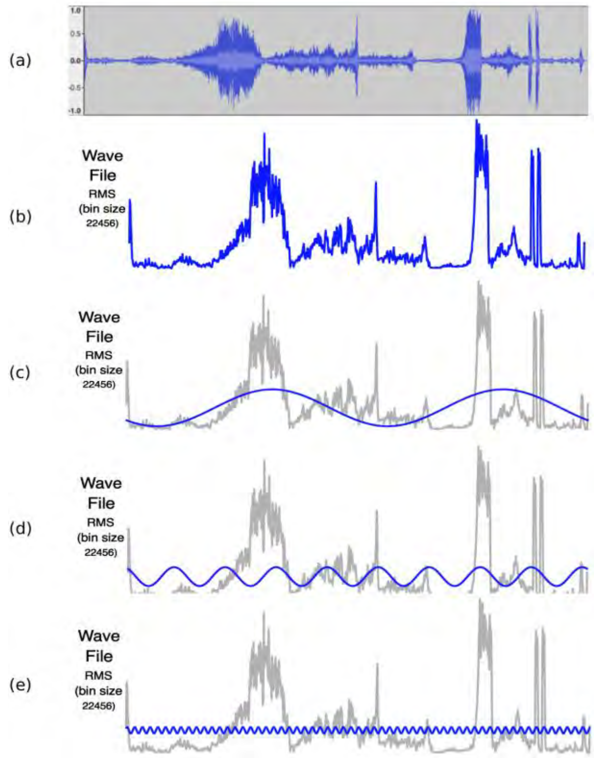

Figure 7. Analysis of the dynamic contour of the *Allegretto* from Beethoven's *Symphony No. 7*. (a) The dynamic shape of the movement as shown in Audacity. (b) The same contour, as represented in "Spectral Musical Contour Explorer." (c), (d), and (e) Three prominent periodicities found at different time scales.

I then used the *SCAMP* libraries for computer-assisted composition in Python (Evanstein, 2018) to orchestrate these different layers of motion, with some instruments playing the larger swells, others playing the mid-level swells, and still others playing the fastest-moving swells.

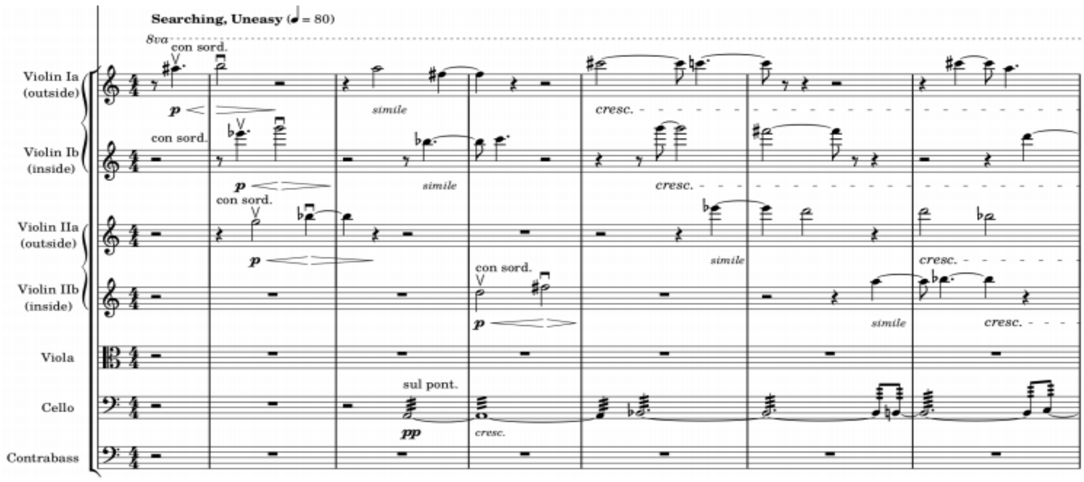

Figure 8. String excerpt from the opening of *Anamnesis*.

Thus, as in *Unraveled*, Fourier Analysis broke a single contour (this time a dynamic contour) into a heterophonic texture of simple gestures. Figure 8 shows an excerpt of the texture in the violins from the opening of the work, consisting of many short, overlapping swells. Below, one can see a larger swell beginning, tremolando, in the cello section.

It should be noted that, as in Adagio Cantabile and Unraveled, the process of musical contour analysis and resynthesis was merely the starting point for the composition. The final work also resulted from numerous other musical processes and decisions, which were largely intuitive in nature.

Conclusions

There are several possible avenues of further research and compositional practice. From the point of view of composition, each new contour represents a different initial condition for the creative process, as does each possible approach to resynthesis (e.g. removing all but the low partials, the odd partials, the prominent partials, etc.). As the above examples illustrate, this approach can generate snatches of musical material (as in *Adagio Cantabile*) and/or it can form the basis of the work's overall form (as in *Anamnesis*).

Possibilities can be further expanded by the development of the tool itself. For example, one could incorporate contours based on other musical parameters: instead of RMS volume, an inputted sound file could be analyzed in terms of its variation in spectral centroid, spread, flux or kurtosis, or on its zero-crossing rate.

Another interesting possibility would be to allow for modification of the phase of partials before resynthesis of the contour. In many cases, the effect of phase is as important as, if not more important than, magnitude in establishing structural boundaries within a data set (Bartolini et al., 2005).

In short, I envision this approach, and the tool I have developed, as one among many that could serve as a source of inspiration for composers in their creative process.

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[1] For those more familiar with Fourier analysis, it will be apparent that I am using a window size equal to the whole length of the melody. There is, therefore, an underlying assumption that the melody itself is cyclic. This may be more or less appropriate in different situations.

[2] In the Pop Goes The Weasel examples above, the inputted MIDI file was monophonic.

[3] The results turned out to be quite interesting with rhythm: When no frequencies (except DC) of oscillation were present, the rhythm was static, with all notes the same length. When lower partials were included, the rhythm started to accelerate and decelerate at the faster and slower parts of the melody. As I included faster and faster oscillations, these accelerandi and decelerandi became more and more local, until all of the detail of the original rhythm was recreated.

Multimedia Analysis in Donny Karsadi‘s Multimedia Piece *I Hate My Stupid Brain*

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Multimedia music has become an important option for 21st century composers. In multimedia music the sound is not the only material that is used, which can present problems when we only see all media correlation through the perspective of sound analysis. Due to this new manner of multimedia music, we have to find another way to analyze and understand how it works. In this paper, author is using Donny Karsadi‘s piece ‘‘I Hate My Stupid Brain“ as an object of analysis and Marko Ciciliani‘s method to examine the way in which multimedia functions in musical works containing multimedia and what we can find from this multimedia relationship that we rarely find in instrumental music.

Keywords: Audiovisual, Multimedia Analysis, New Music.

Composers in the present time do not only sit on their chair and write notation as representation of their sound idea or directly use sound material as compositional materials that are processed using electronic tools. Composers also expand their skill to realize their art through mastering video editing software, VJ tools, film and photo cameras, staging, lighting, program languages, communication protocols, working with microprocessors, physical computing, soldering, tailoring, book layout, and more (Ciciliani 2017: 27).

Those extra skills enable composers to create multimedia music with the involvement of other media such as lighting projection, visual projection, text, etc. we can see the example of the involvement of other media in multimedia music such as in Michael Beil’s piece “Key Jack” which he involved the use of live video content, in Marko Ciciliani’s piece “Alias” where the lighting projection become one of materials in this piece, or like in Jagoda Szmytka’s “DIY or DIE” where she involved the use of specific costumes, materials and staging.

Based on those examples, we can see in multimedia music, the sound is not the only material that is used, which can present problems when we only see all media correlation through the perspective of sound analysis. Thus, to fully gain the understanding of multimedia music, we have to analyze how the relationship among media are built and connected to each other.

In this paper, author would like to use Donny Karsadi’s piece “I Hate My Stupid Brain” as an object of analysis to examine the way in which multimedia functions in musical works containing multimedia and what phenomenon that we can find from multimedia relationship that we rarely find in instrumental music.

The Piece

I Hate My Stupid Brain is a multimedia piece by Indonesian composer Donny Karsadi. Donny Karsadi studied composition under Otto Sidharta and Prof. Bernd Asmus at Pelita Harapan University, Jakarta, Indonesia. After Graduating, he continued to study composition with Dieter Mack at Musikhochschule Lübeck. His passion for electronic medium came slowly during his time in Lübeck as he learned electronic music under Prof. Sascha Lino Lemke and also sensors and video techniques under Alexander Schubert. He also decided to take on another degree in electroacoustic composition under Prof. Kilian Schwoon and study audio programing under Joachim Heintz at Hochschule für Künste Bremen.

I Hate My Stupid Brain is a multimedia music for one performer, live projection and lights, and live electronics. According to Donny, this piece was composed within the duration two or three weeks and was a lot different (read: kind of “prototype”) from Karsadi’s original idea. The original idea itself will be realized in a new piece by Karsadi which will be performed in 2020 titled “Nrimo Ing Pandum” for computer keyboard, motion sensors, projection, lights and live electronics. However, for the purpose of this analysis, I will more focus on Donny Karsadi’s piece “I Hate My Stupid Brain”.

The setup of “I Hate My Stupid Brain “in the Youtube video I have sourced for my analysis shows several differences with original set where the ideal position of the guitarist should be in the “projection space”. The guitarist must be in the middle between the visual projection of the guitar sound on the left and right, and the guitarist must be under the visual projection of the AI sound. In this analysis, author will use Donny Karsadi's piece "I Hate My Stupid Brain" based on video recording that was uploaded on Youtube.

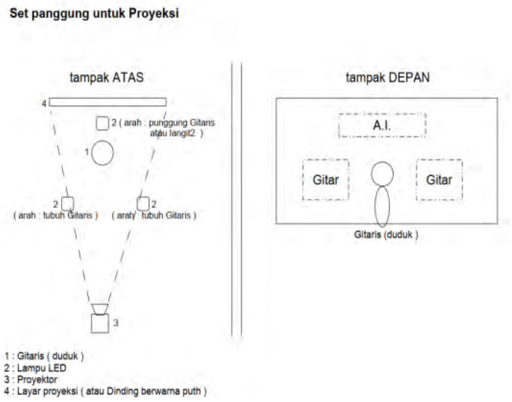

Figure 1. Original setup. Sketch by Donny Karsadi.

Karsadi explained in an email that this piece was "divided" into three sections where the light projection, guitar sound and live electronic followed by texts (the transcription of the text will be explained in the next chapter) projected to a screen as the opening of the first section.

In the second section, the text is gone from the screen and only guitar sound, live electronic and light projection are left with more "agitated" characteristics in comparison to the first section in terms of rhytmical gesture.

In the third section, the characteristic is contrasting and extremely flowing, the visual comes back to the screen but this time with different shapes, close to cubistic pattern and the text disapears from the screen. In the interview arranged by e-mail, Karsadi explains the whole piece using a metaphor:

> About the idea, maybe it can be linked to a silly romance. I prefer to explain by this analogy: The story of someone who feels lonely, then try to "pedekate" (read: flirting) on A.I like Siri/Alexa (section 1) and failed, even ended up fighting. Then try to distract, look for other activity by playing a few interrupted phrases (section 2). Until finally felt bored and fell asleep (section 3). The first and the third section have similar nuances (abstract), while for the second it's more playful, the beats and notes are a bit clearer and can be followed. So, the three sections have this kind of structure "abstract - less or even a little abstract – abstract" (Septian Dwi Cahyo, private email, 12th May, 2020).

What author found interesting in this piece is how the guitar and AI voice "communicates" in the first section which is projected into the text on the screen. Those two sound sources (guitar and AI voice) were transcribed into the text. The text projections for the guitar sound are abstract, because the phrases played by the guitar are also abstract. On the other side the AI voice speaks in English and has "translation/subtitle" where the translation/subtitle is projected on the screen and is completely different from what AI voice said.

The Used Method

There are some methods to understand how auditory and visual elements works in multimedia. Two of them are from Shin-Ichiro Iwamiya and Marko Ciciliani. In Shin-Ichiro Iwamiya, the phenomenon of auditory and visual combination in multimedia only divided into two categories, formal congruency and semantic congruency.

In Iwamiya paper, formal congruency defined as the matching of auditory and visual temporal structure (Iwamiya, 2013: 141). It provides a united perceptual form to auditory and visual information. Another category is semantic congruency. Semantic congruency is defined as the similarity between auditory and visual affective impression (Iwamiya 2013: 141). It helps to communicate the meaning of audiovisual content to perceiver.

However, for this analysis, author prefer to use Marko Ciciliani's method, because it has more categories that fit to analyze the congruence/divergence among the media and investigate the relationship between the media used in this piece. This method is used to analyze audiovisual and multimedia in order to "dissect" the relationship between media, such as event synchronization, semantic correspondence, etc.

There are three categories with its parameters that can be used as tools to investigate the relationship, congruence/divergence between media:

1. Category of Mapping
2. Category of Indices
3. Category of Atmosphere

1 Category of Mapping

There are three parameters in this category such as divergence/congruence in terms of synchrony, divergence/congruence in terms of space, divergence/congruence in terms of mass.

1.1 Divergence/congruence in terms of synchrony. In this parameter congruencies or divergences are in terms of synchrony where the visual event is associated with an aural one, and it is necessary that they occur simultaneously. This parameter indicates whether auditory and visual phenomena are predominantly synchronized (Ciciliani 2017: 478).

1.2 Divergence/congruence in terms of space. The second parameter of this category refers to space and indicates if the spatial arrangement of sounds and elements in the image correspond spatially (Ciciliani 2017: 478).

1.3 Divergence/congruence in terms of mass. The third parameter indicates if sonic and the visual phenomenon correspond in terms of size or apparent weight. For example larger objects in the visual part are associated with lower or louder sound.

2 Category of Indices

This category has only two parameters, divergence or congruence in terms of content and divergence or congruence in term of idiom.

2.1 Divergence/congruence in terms of semantics. This parameter indicates whether an audiovisual work exhibits a profiled relationship between media of a semantic nature. Here semantic refers to any meaning that is superordinate to what is evident as a visual or aural phenomenon. These can be a concrete meaning – as in a narrative context, a symbolic reference, or emergence meaning (Ciciliani, 2017: 478).

2.2 Divergence/congruence in terms of idiom. This parameter expresses whether there is congruence or divergence between the idioms or styles that each medium uses (Ciciliani, 2017: 479).

3 Category of Atmosphere

Three parameters in this category of the atmosphere are describing characteristics of relationship between media, that are rather evasive and that cannot easily be attributed to a single concrete principle.

3.1 Divergence/congruence in terms of kinetics. This parameter has "similarity" with the parameter of synchrony. But if in the parameter of synchrony the synchronization is closer to "rhythm" synchronization, then this parameter refers to a more general sense of motion, pacing and speed.

3.2 Divergence/congruence in terms of salience/fidelity. This parameter describes the balance between different media and whether one strongly dominates over the other (salience), or whether one is designed in much greater detail than the other (fidelity) (Ciciliani, 2017: 479).

3.3 Divergence/congruence in terms of tinting. This parameter addresses perhaps the least tangible aspects of a work, namely the general moods that the media express – here expressed as tinting (Ciciliani, 2017: 479).

Discussion

This analysis is divided into three parts following Donny Karsadi's piece structure. In the first part I will focus on analyzing the relationship among media, particularly the relationship between the text projected on the screen and the sound from guitar and AI voice.

In the second part, since the text represented by guitar and AI voice is gone, I will focus on analyzing the congruency between the sound and the light.

In the third part, I will analyze the congruency between new visual materials in the screen, the light and the sound. I will use Marko Ciciliani's method as point of departure to analyze congruencies among media in Donny Karsadi's piece.

1 First Section Analysis

The first section take place between minute 00'.00" and 03'.06". In the beginning of this section, from 00'.00" - 00'.28" we can see congruence in term of synchrony which happens accentuations in the sound are synchronized with accentuations in the light projection.

After this opening, the work proceeds to a part without accentuations of the light projection. In this part from 00'.28'' - 02'.24'' AI voice, the sound and the text on the screen begin to play simultaneously.

Upon first experience we might find these three mediums are moving arbitrarily and without any materials that connect those mediums. However, from Donny emailed statement, we can see if there is congruence in terms of idiom where the guitar sound described by Donny as an abstract material has congruency with the abstract letters style in the text projected on the screen:

> The guitar player ''flirting" the AI. The projection for the guitar sound is abstract, because the phrases played by the guitar are also abstract. Siri (AI voice) speaks in English and she has a "translation/subtitle" whose contents are completely different from what she said. For example she said "yes" in the spoken voice part, but actually she meant "no" in the text part (Septian Dwi Cahyo, private email, 12th May, 2020).

We can see if there is congruence in terms of idiom where the guitar sound described by Donny as an abstract material has a congruency with the abstract letters style in the text projected on the screen.

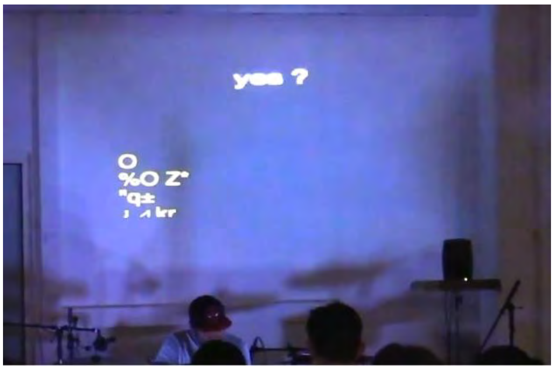

Figure 2. Abstract letters and AI voice "subtitle/translation" .

Regarding the relationship between the AI voice and the projected text is completely different from what AI voice speaks. Here is the transcription between the AI voice and the projected text that has a role as translation/subtitle of the AI voice. On the left side are the spoken part of AI voice, and the right side in the brackets are the translation/subtitle of the AI voice in the form of the text that projected in the screen:

- Hello there (yes?)
- How can I help you (what do you want?)
- No worries (argh…)
- It is my pleasure to help (what a pain the a@^!\>>)
- oh (bah)
- I'm single, how about you (it's none of your f#%아킹 business)
- that's unfortunate (haha..)
- I wish you found someone in the near future (loser..)
- What (huh?)
- I'm here to assist you with your needs (what a perv..)
- oh (ew..)
- not that kind of needs (get the fudge out of here!)
- sure (well)
- please wait a moment (sit your a &/!"§ss?' down)
- I'm trying to find the best way (I'll go and take a dump)
- Search completed and find no best way other than K.I.L.L. yourself (oh, you're still here.. hmmm.. I though you left already.. I cooked yome meatloaf, do you want some?)
- oh (awe..)
- you ungrateful son of a bi$!tch (that's so sweet of you)
- no (yes)
- you (you are..)
- you son of a bi$!tch (you are so charming)
- Okay then (I see..)
- I'll tell them to pull you down (then I'm going to hold you in my arms)
- pin you hard (and never let you go)
- and shit directly into your mouth (and shower you with thousands of kisses)
- what do you say about that (what do you say to that?)
- Okay (oh okay then..)
- I can just shoot your mouth with a B.B Gun (whatever you say, I'll follow you 'til the end of the world)
- you don't like that (I know you'll love that idea)
- then (so)
- Fu!$%ck off (come closer)
- Goodbye handsome (closer)
- Wish you have a nice day (closer)

From this AI voice and its translation/subtitle that projected as text on screen, at glance we can see if no congruence happen in that part. However, if we look at Donny statement:

> For example she said "yes" in the spoken voice part, but actually she meant "no" in the text part.

We can see a strong sign that the AI voice and its translation/subtitle has a "hidden" relationship that gives semantic information, where the AI voice tries to be polite to the guitar part that "flirt" her. However, her response is opposite and it is projected on the screen.

This "hidden" relationship remind author of *Gehalt* aesthetic and relational music idea by Harry Lehmann. The German concept of "*Gehalt"* cannot be precisely translated into English. The *Gehalt* of an artworks is not the traditional pre-existent "content", but rather must be experienced by the recipient through the process of interpretation (Lehmann, 2006: 31).

This G*ehalt* can only appear in relational music. If we compare to program music where the extra musical such as movements, images and language can also be completely musicalized, i.e. transform into musical material. Relational music, on the other hand, retains its reference to the world, its reference to something that is no longer music (Lehmann, n.d.).

In relational music, the musical relatum (text, images, videos, etc) present as it is and not transform into musical material. The *Gehalt* in relational music happen when each media (music, text, visual) boost a semantic relationship. This *Gehalt* in Karsadi's piece appear when the spoken text by AI voice is in opposite with its translation/subtitle that projected as text on screen that give "hidden" meaning to guitar sound that "flirt" the AI.

That part is kind of symbolic reference of "rejection" which is close enough to the congruence in terms of content where semantic refers to any meaning and these can be a concrete meaning – as in a narrative context, a symbolic reference, or emergent meaning.

Start from minute 02'.23" and lasting through 03'.08", the text is gone and the light and sound start to show a congruence in terms of synchrony again where the electronic sound "accentuation" is synchronized with the light projection "accentuation". In this part the AI voice only appears a little bit until this AI voice functions as a reverb effect that brings the piece toward the second part.

In this transition to the second section there is congruence in terms of space that happen between minute 03'.03" - 03'.07" where live pulse electronic sound is in the center of loudspeaker matched with the light projection position in the center. This part besides showing congruence in terms of space, also demonstrates congruence in terms of synchrony between sound and light projection rhythm.

To summarize the analysis from each section, author will use Marko Ciciliani's valence, potency and activity graphic. This graphic enables us to give parameter values from each divergence or congruence that happens in a piece that we analyze. This graphic contained each categories with its parameters. In each parameter there is line that indicates the value of categories and parameters in which the right side shows relevant and congruence values. On the other hand, the left side indicates irrelevant and divergence value. Below is the valence, potency, activity of the first section.

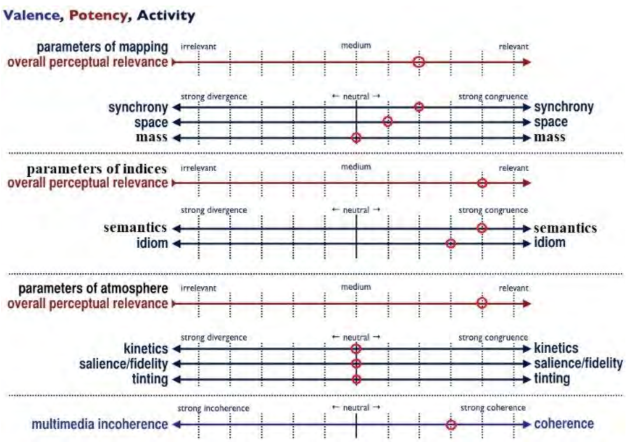

Figure 3. Valence, potency, activity of the first section.

2 Second Section Analysis

The second section starts in minute 03'.09" - 05'.44". The character of this section is more rhythmical than the first section. We also can find the congruence in terms of synchrony and tinting dominating this part where the light and the sound is matched in terms of rhythmic synchronicity.

Start from minute 04'.50" - 05'.00" the characteristic slightly change for a while. Here, we can see that the congruence in terms of kinetics happen in this part when the sound and the light begin to slow down the tempo for ten seconds before returning to the previous rhythmical character.

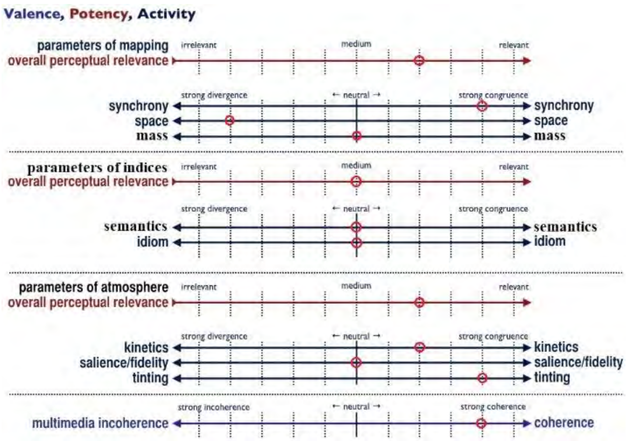

Figure 4. Valence, potency, activity of the second.

The congruence in terms of tinting also seems to dominate the second section of this piece. Between minute 05'.30" - 05'.47" the congruence in terms of kinetics start to appear again when the tempo of the sound and the light projection start to increase to emphasize the transition part toward the third section. Overall, the second section contains three congruencies including congruence in terms of tinting, congruence in terms of synchrony, congruence in terms of kinetics. In the second section, the sound that represent the light projection in minute 03'.03" - 03'.37" appear again, this time the sound move from right to left and vice versa in minute 04'.04" to 04'.27" but the light projection remain in the center position showing divergence in terms of space.

3 Third Section Analysis

The third section starts from minute 05'.43" - 08'20". The characteristic of this section is less rhythmical and more flowing. If we use Donny's metaphor, we can say this section is more abstract than the second section. The mood of the light projection and the sound is very close to congruence in terms of tinting, this combined with congruence in terms of kinetics where the light and the sound give sense of slow motion and to ‘‘resolve‘‘ the hectic gesture of the second section.

What author found interesting in this section is the new visual material that appears on the screen. Some cubistic patterns that blink with a fast tempo remind me of the second section gesture from minute 05‘.41“ - 07‘.45“. It gives ‘‘semantic‘‘ information and juxtaposed in author perception. This creates multiple layers of congruences.

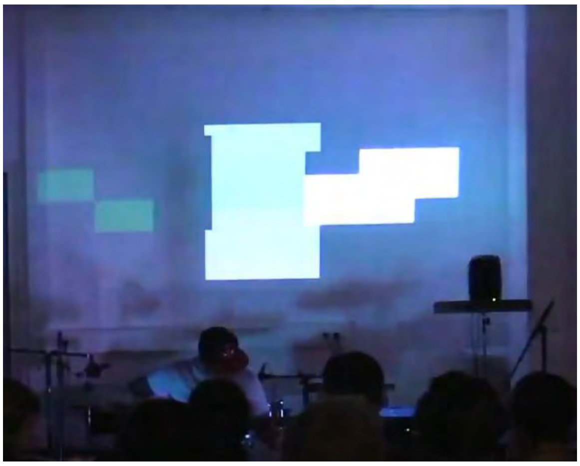

Figure 5. Cubistic pattern in the third section.

At the end of this section circa minute 07‘.57“ we can see a juxtaposition of congruencies again between congruence in terms of synchrony and congruence in terms of kinetics when the light projection, cubistic visual and the sound is match in terms of rhythmic synchronicity and the increasing of sound amplitude plus its juxtapose sound layer give a sense of acceleration through the end.

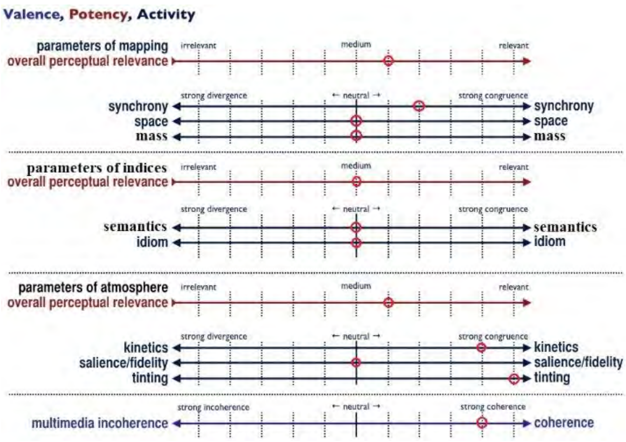

Figure 6. Valence, potency, activity of the third section.

Overall Analysis Graphic

To summarize the analysis from the first section to the third section, author will use different shapes of Marko Ciciliani’s valence, potency and activity graphic. This graphic is a bit different in comparison to the graphic in each section. There is a dotted line in the centre, which divides the congruent half from divergent. This graphic also enables us to give parameter values from each divergence or congruence and relevant or irrelevant value that happen in a piece that we analyze. This graphic also contain each category with its parameters.

In each parameter there is a dotted line in the center to divide the congruence and divergence part. If we put dots as parameter value indication above the center dotted line, it represents more congruence rather than divergence, and the higher the given congruence value, the higher congruence value happens in that parameter. If we put dots as parameter value indication below the center line, it represents more divergence rather than congruence, and the lower we put the dots below the center dotted line, the higher divergence value happens in that parameter. On the other hand, if we put the dots in the center dotted line, then it means the value is neutral between congruence and divergence.

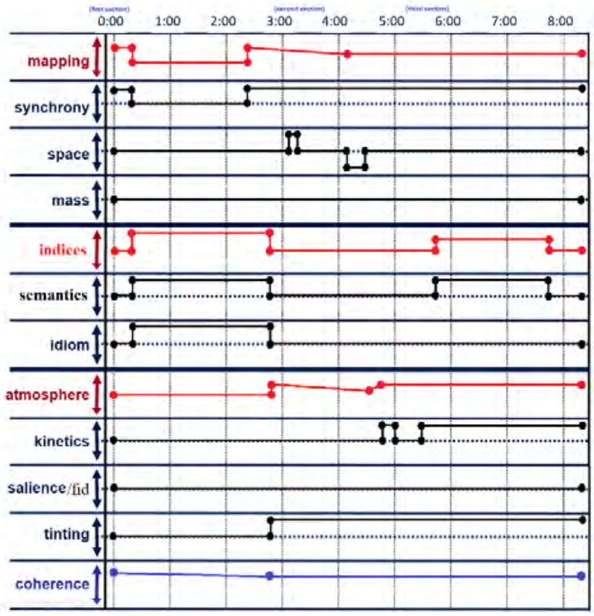

Figure 7. Valence, potency, activity of all sections.

Conclusion

Based on Donny’s piece case and Marko Ciciliani’s method explanation, we can see if multi medium in multimedia music works by combining many aspects of media. This multimedia combination not as an arbitrary activities or just as support from one media to accompany another media, but it has balance role between media. This combination of media has its own correlation and congruence. Style congruence between media, semantic congruence, etc.

Another interesting phenomenon that we rarely see in instrumental composition is how the multimedia music can give more space. What author mean with more space here is through the use of multimedia composers are able to put semantic information through "hidden" relationship or *Gehalt* that is produced by combination of each media that boost some perception layers simultaneously such as visual perception, sound perception and so on.

The "hidden" relationship create semantic information produced by juxtaposed activities between media, where one media gives information to another media, such as in the first section of Karsadi's piece. This "hidden" relationship shows "semantic" meaning of the opposite phenomena of the spoken text produced by AI voice and projected text in the screen that give "semantic" answer to the "flirt" activity that guitar part did.

Acknowledgments. I would like to thank Donny Karsadi for his help to answer some questions for this analysis purpose. I also thank Alyssa Aska and Putu Tasya Sanjivani Oka for their help to examine this paper.

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Video Example

Karsadi, Donny: *I Hate My Stupid Brain*, 2018, https://www.youtube.com/watch?v=GEYTO3uSm4k [August 20, 2020].

Visiting the Virtual: Performance Practice in the Virtual Artworks of Rob Hamilton and Christof Ressi

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When moving in the context of computer games, contemporary multimedia music and classical instrumental performance practice, we find ourselves confronted with the different creative aesthetics and goals, agents, and peer groups that are pertinent to each specific context. This multiplicity not only affects the works created, but also has an impact on the audience's expectations and perceptions. It also touches the work of the performer on several levels. In "Visiting the Virtual," I will explore the manner in which elements of computer games incorporated into audiovisual artwork in live concert situations achieve an aesthetic effect and performative impact on both the work of the performer and the audience's perception.

Keywords: Game-related audiovisual composition, virtual reality, agency in performance, computer games, contemporary multimedia music

The artistic research project *GAPPP – Gamified Audiovisual Performance and Performance Practice*, which offered me the framework for this investigation, was funded by the Austrian Science Fund as a multiannual project in artistic research (PEEK AR 364-G24). The project was conceived and led by the composer and audiovisual artist Marko Ciciliani. It ran from 2016 to 2020 and was based at the Institute of Electronic Music and Acoustics (IEM) of the University of Music and Performing Arts Graz. With GAPPP we set out to develop a thorough understanding of the potential of game-based elements in audiovisual works in the context of contemporary Western art music. New audiovisual works formed the point of departure for our research. These works were created for GAPPP, each addressing specific research questions we wanted to investigate. While one main focus lay on musical applications, all artistic projects that emerged were conceived as audiovisual art, and accordingly the visual and interactive components of the artworks have been as important for our investigation as the musical elements.

This article is part of the monograph *Ludified* (edited by Marko Ciciliani, Barbara Lüneburg and Andreas Pirchner to be released in January 2021), and is published here with the kind permission of the publisher The Green Box, Berlin.

Introduction and Research Questions

When moving in the context of computer games, contemporary multimedia music and classical instrumental performance practice as we do in GAPPP, we find ourselves confronted with the different creative aesthetics and goals, agents, and peer groups that are pertinent to each specific context. This multiplicity not only affects the works created, but also has an impact on the audience's expectations and perceptions. It also touches the work of the performer on several levels.

In "Visiting the Virtual," I will explore the manner in which elements of computer games incorporated into audiovisual artwork in live concert situations achieve an aesthetic effect and performative impact on both the work of the performer and the audience's perception. Furthermore, I will explore how the use of virtual reality influences this situation. I will do so by looking in detail at two different case studies, Movement II of *Trois Machins de la Grâce Aimante* (2018), a virtual reality string quartet by Rob Hamilton, and *Terrain Studies* (2019), an audiovisual composition for solo instrumentalist and virtual reality system by Christof Ressi. Both works are located within a 'virtual reality' that unfolds behind the VR glasses of the performer(s) and a 'physical reality' that is shared with the audience and bears traces of the virtual. My investigation of these cases will therefore address the representational spaces in which the works unfold, namely the physical space of the concert performance and the virtual space in which large parts of the performance take place.

Following on from two earlier papers of mine that were concerned with other GAPPP works (Lüneburg 2018a and b),[2] I will touch on questions such as: how does the space of possibility afforded to the performer through the game system, software design, and interfaces influence the players' ludic and performative involvement and range of expression in live concert situations? How do the different spaces influence the performers' tasks and the audience's perception? How prominently does the audience experience associations with games and how is this feeling established in both audience and performers?

Analytical Tool and Theoretical Background: Ciciliani's Polar Diagram and the "Space of Possibility"

My analysis of Hamilton's and Ressi's works seeks to identify creative agencies in the system design and interactivity that give the performer a sense of meaningfulness. According to Salen and Zimmermann, "*Meaningful play* occurs when the relationship between actions and outcomes in a game are both *discernible* and *integrated* into the larger context of the game" (Salen and Zimmermann 2004, p. 34). In GAPPP works, meaningful play is pertinent to the particular space of possibility they offer. This "space of possibility" is the space of all possible actions and meanings that can emerge during the performance of the ludified artwork. This concept ties together meaning, design systems, and interactivity, and directly influences the performers' creative strategies and goals, musical objectives, and capacity to share their artistic experiences with the audience.

In order to include both an internal and external perspective in my research, I draw data from my own artistic observations as a performer of both works and from the collaboration with composers and coplayers. Additionally, I code and analyze interviews with composers, performers and audience focus groups. Audio and video documentation from GAPPP's work labs and lab concerts complete the data collection and offer a further source of information when analyzing the artworks and situations in question. I apply Marko Ciciliani's polar diagram for the analysis of gamified audiovisual works (see figure 1) as a tool with which to analyze the two case studies. Since the polar diagram is explained in detail in the chapter "A Polar Diagram for the Analysis of Gamified Audiovisual Works," I will offer only a brief summary of its structure and my use of it here.

The polar diagram was created as a visualization tool that provides an overview over key criteria relevant for ludified works. The diagram is divided into an upper half, which describes the work with regard to aspects of its composition, and a lower half, which reveals the performance-related perspective. Five continuous axes cross both halves, called interface axis, determinism axis, agency axis, presence axis, and ludus axis. Each depicts two parameters that refer either to the same or to closely related phenomena.

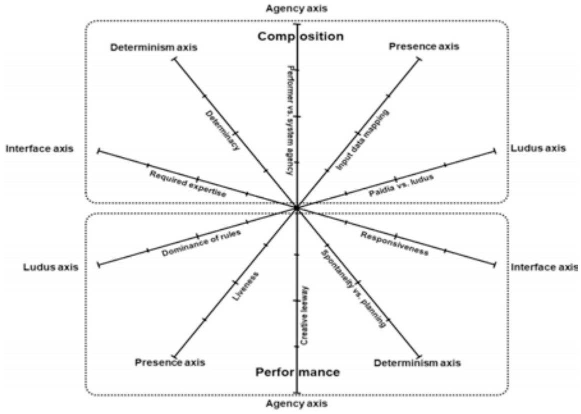

Figure 1. Polar diagram developed by Marko Ciciliani to describe ludified audiovisual compositions and the criteria that determine their space of possibility.

The interface axis visualizes how much expertise the performer requires to use the interface of an artwork and its responsiveness to the performer's actions. The determinism axis relates to the technological system's algorithmic configuration. It depicts the degree of determinism given through the compositional system and how this translates to the performer. On the performance side it indicates whether the underlying ludified interactive system requires spontaneous actions and decisions, or whether it allows the performer to plan the interpretation of all the performance's details. The third axis represents the musical and performative agency of the performer in comparison to the agency of the system and the creative leeway granted to the player. The presence axis illustrates how input data is mapped in the artistic result. On the performance side of the diagram, the term "liveness" signifies how "aesthetically meaningful differences in the input sound are mapped to aesthetically meaningful differences in the output sound" (Croft 2007, p. 61). In other words, this parameter indicates to which degree the system is experienced as an extension of the instrument the performer uses. It includes not only the sonic representation but also potential visual translations of the performers' actions. On the diagram's compositional half, the complementary term "input data mapping" refers to the quantity of data extracted from the performers' playing that are used to trigger sonic or visual events.

The ludus axis demonstrates where the emphasis lies within the gamified system: on either ludus or paidia on the composition half, or on the dominance of rules (game-driven versus performance-driven rules of play) on the performance half. I adopt the definitions of "ludus" and "paidia" by game researchers Salen and Zimmerman (2004), who define these categories as addressing "a structural understanding of games, a continuum of relationships between structure and play. If for example play edged closer to the ludus end of the spectrum the rules become tighter and more influential. Located on the other end of the spectrum, paidia-based play eschews rigid formal structures in exchange for more free-wheeling play" (Salen and Zimmerman 2004, p. 309).

In the diagram, the values for each parameter are marked graphically. By connecting these marks, a shape results that allows for an intuitive comparison of graphs based on different works. In the following analyses, I concentrate on the agencies and interfaces given to the performers and their influence on the players' ludic and performative involvement. I investigate the way in which the systems developed further the range of expression in live concert situations and the conditions for the players' inner involvement or noninvolvement. A special focus will lie on comments by members of the audience, which serve as an external perspective (for a detailed description of the demographics of the audience, cf. "lab concert" in the Glossary in this volume).

Having defined the underlying terms and briefly explained the polar diagram, I will now investigate the following two case studies: Movement II of *Trois Machins de la Grâce Aimante* by Rob Hamilton and Christof Ressi's *Terrain Studies*. I analyze Ressi's work from the perspective of my own performance at the world premiere. For this book, however, *Terrain Studies* has been documented in the performance of clarinet player Szilárd Benes, Christof's long-time collaborative artistic partner.

Case study 1: Rob Hamilton's *Trois Machins de la Grâce Aimante*

Rob Hamilton's *Trois Machins de la Grâce Aimante* is an artwork for a virtual reality string quartet and a computer system. Its second movement was premiered in 2018 at the Cube of the IEM Graz by Barbara Lüneburg (1st violin), Osman Eyublu (2nd violin), Francesca Piccioni (viola), Myriam García Fidalgo (violoncello), and Rob Hamilton (VR system), the same instrumentalists who are featured in the documentation on the included USB stick. In this work, the musicians do not perform on their acoustic instruments, but on the "Coretet", which is a family of virtual musical instruments. The Coretet's concept and design stems directly from traditional string instruments (violin, viola, and violoncello). However, the Coretet itself is entirely virtual and played via a VR system. The players sit back to back and their faces are covered by VR goggles. Through the goggles, they see their virtual instruments, which they control througsh wireless controllers and by emulating the typical movements of playing physical string instruments.

Figure 2. Performers on the virtual instrument "Coretet". © ndbewegtbild

In Rob Hamilton's own words, in *Trois Machins de la Grâce Aimante* he explores the 'virtual' versus the 'real' through the performers' musical and performative handling of the digital instrument Coretet.

> I built a virtual model that allows the performers to use the same performative gesture that they learned on acoustic instruments to push data into this virtual model. So, with the goal of making this feel and sound and act like a traditional bowed instrument, we can then depart and do anything … The focus here is on the instrument and on the performers. (Hamilton 2018)

Visually, the string quartet is represented in three forms: as a projected highly stylized image of its avatars on the main-stage screen, through the bodily performance of the players on stage, and as an image of their individual instrument projected behind the players' VR glasses. Hamilton uses physical modelling to computationally simulate the reaction of a string to bow pressure and velocity, as well as to being played by different parts of a bow.

> However this sound, while it sounds like a string, it does not sound like a violin or a cello. There is an incredible rich harmonic spectrum that is abrasive and distorted and has all kinds of bizarre non-linear characteristics that are hard to control, and yet, these performers are doing a great job controlling it. So working with this constraint, forced me to really focus on making the instrument behave in a traditional sense, even though it is already an extension of that tradition. (Hamilton 2018)

The instrumentalists explore the Coretet in the given virtual environment and play with it without any predetermined game-related obligations, such as fulfilling specified objectives or following goals. Their performance space is the world that unfolds behind their VR goggles, which is designed as a white space that is additionally projected onto the main-stage screen for the audience: "My intention was that this was a neutral, blank space … There is no semantic content in that environment, no context that I am trying to convey as an artist at all" (Hamilton 2018). However, the performers' field of vision is filled first and foremost by their own virtual instrument. If they want to see their fellow musicians, who are depicted as abstract avatars hovering in the virtual void, they have to deliberately turn towards them.

> The relationship of how the performers are sitting in physical space versus in virtual space has become very interesting in that in physical space the performers are seated in a circle facing away one from another, and yet, the representations in virtual space are exactly the opposite: facing one another in traditional string quartet formation. (Hamilton 2018)

The musicians' sensory experience is split. Their instruments are virtual without a physical body, which means that the musicians are literally playing the air. Their visual experience is determined by the virtual view behind their VR glasses, their sonic experience is based in the physical reality transmitted through the loudspeakers of the performance space, and their haptic experience is reduced to pushing the buttons of their controllers and moving their arms through the air while emulating string player movements. They have to perform in two worlds: the virtual world in which they create the music, and the physical world in which the audience subsequently experiences it.

In musical terms, the performers are guided by a graphical score on the basis of which they improvise and explore the Coretet. The score subdivides Movement II[3] of *Trois Machins de la Grâce Aimante* into six parts while indicating the formal build-up and musical atmospheres. Hamilton allocates a different harmonic principle to each section of the movement by quantizing the fingerboard of the virtual instrument according to different pitch-class settings. He traverses the range by increasingly diminishing the pitch intervals in each section from major triads to a pentatonic scale, a whole-tone scale, a chromatic scale, and finally a nonquantized scale that offers free choice of pitch. The musicians' actions are focused upon exploring both the music and the virtual instrument. From the audience's perspective, the projection of the virtual environment onto the main screen and stage props such as individual computers for each player, wearables such as VR glasses and game controllers, and even the playful staging of the quartet back to back effectively set the stage in terms of the game experience.

Next I will apply the polar diagram to the second movement of *Trois Machins de la Grâce Aimante*. Before I do so, I would like to highlight that I am talking about an experience with a virtual instrument that at that time existed as a prototype only and had never been tested before in a concert situation. Difficulties and limitations in handling the instrument were to be expected. And although we will hear criticism from the performers, they also saw great potential in the instrument and enjoyed performing *Trois Machins de la Grâce Aimante*. Hamilton has developed a highly sophisticated setting with great artistic promise of which we will hopefully hear and see more in the future.

Applying the Polar Diagram to *Trois Machins de la Grâce Aimante*

Hamilton describes his composition as feeding from traditional instrumental performance practice, and the instrument Coretet as meant to be played by expert string players: "From the time of its inception, *Trois Machins de la Grâce Aimante* was intended to exist as a composition firmly descended from traditional ensemble instrumental performance practices with a goal of exploring how virtual implementations of musical instruments could leverage learned expert behaviors of highly skilled musicians" (cf. the chapter "Composing (and Designing) *Trois Machins de la Grâce Aimante*"). Since Hamilton implements compositional rules rather than game-related rules in *Trois Machins de la Grâce Aimante,* I will apply the upper half of the polar diagram to purely compositional rather than game-related parameters in my following analysis.

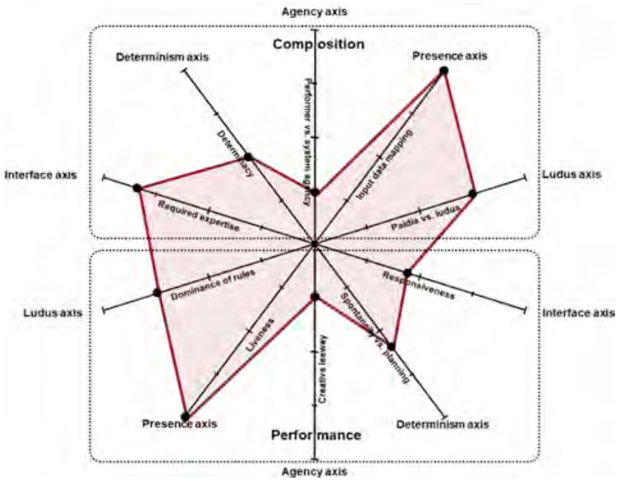

Figure 3. Polar diagram for Rob Hamilton's *Trois Machins de la Grâce Aimante.*

Indeed, the polar diagram indicates the use of an interface, the Coretet, that on the compositional side requires its user to be highly specialized, while the performance side of the diagram indicates only a medium degree of responsiveness. This is partly due to the lack of the haptic and tactile feedback that the performers are used to from their physical instruments, which is missing from the virtual instrument. In the focus group interview that we conducted with the members of the quartet, it became clear that the performers struggled for instance with the controllers that replace their normal instrument and the bow. Interview partner 2 (IP2) recounts:

> There was the bow issue: I find the game controller that we use instead of a bow extremely sensitive, in fact too sensitive. It responds to many of my movements that would not make any difference with a physical bow, which causes problems. Of course you can turn every problem into something expressive, but here I think this is very difficult. (Quartet 2018, IP2)

In the performers' opinion, some of the instrumental registers are not yet well adjusted and they feel that the control they have of timbral sound color needs to be improved.

> I usually play in high registers and avoid the low, because the lower frequencies come with a lot of noise. Sometimes it sounds more like a 'swoosh' than an ordinary tone. I know, there is the concept implemented in the instrument that you can control how much noise you have in the sound, but this I think can still be improved a bit. (Quartet 2018, IP3)

However, the performers see potential for development, both concerning the instrument itself and in their learning of how to handle it:

> We are experiencing limitations. Some features do not react as fast as we expect them to do from being used to a normal instrument. And for some things we would perhaps need more training to be able to play more exactly and have more control. We are still struggling a bit with how the machine is reacting, but many features do work. (Quartet 2018, IP2)

> We cannot control the pressure of the bow [to influence the dynamics], but we realized that we can replace it with bow speed. Even if there are lots of things that don't function like with a real instrument, being an instrumentalist and knowing of all the possibilities that you have helps to replace some of the techniques in a way that works on the virtual instrument. (Quartet 2018, IP1)

The determinism axis shows a balance between the system's degree of determinism and the performers' resulting feeling of predictability. Both lie within a medium range. The compositional setup—that is, the graphical score—made for relatively strong determinism by providing playing instructions with regard to form, the choice of harmonic scales, and the musical atmospheres of the six sections of Movement II. On the other hand, like all graphical scores it left scope for artistic creativity. Accordingly, the musicians felt that planning was both possible and required, but that creative spontaneity was desired as well and showed in the score's improvisational aspect. Moreover, the determinism factor is strongly influenced by the virtual interface, which is at the center of the composition, and its to some extent unpredictable behavior. The musicians' musical planning was thus counterbalanced by the spontaneity they needed to react to the fragile behavior and peculiarities of the Coretet.

On the agency axis, we find that the compositional and system agency ranks considerably higher than the personal agency perceived by the performers. They found for instance that the representational space of the virtual reality comes with a limited field of vision, making it difficult to see their coperformers in the virtual realm and even more difficult to interpret their actions based on the stylized avatars, of which they only see unconnected elements: the shape of a head, a hovering instrument pointing in the wrong direction, a disconnected bow, and a randomly flying hand (see figure 4). They felt that this reduced their musical agency and capacity to make chamber music in the physical concert space. "We want to play together but it is almost impossible to play exactly in unison, which would not be a problem with a normal instrument" (Quartet 2018, IP2).

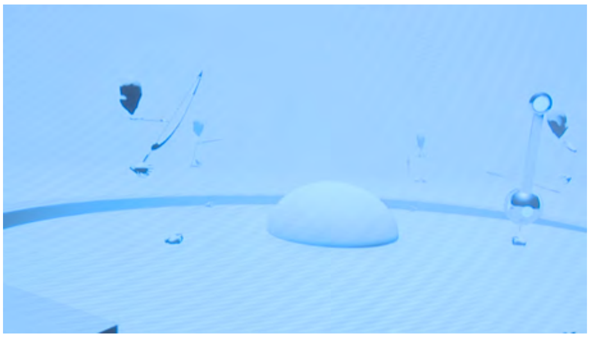

Figure 4. The highly stylized avatars appear behind their VR glasses and are visible to the audience on the main performance screen. © ndbewegtbild)

The Coretet the musicians performed on existed only in a prototype version that was still in development at the time of their playing. Its (yet) existing limitations had an impact on their musical agency. The performers worked with a number of harmonic schemes set by the composer that were mapped onto the Coretet meaning that they could not freely shape the harmony or melodies or break the given tonal system in their improvisation. Thus, the system in its prototype version allowed for relatively little creative leeway in terms of making chamber music, forming a phrase or a melody, influencing harmonic events, producing concise rhythms, and controlling the bow articulation.

> If I try to play staccato really loudly, I pass right through the instrument, since there is no physical body, no strings, that would stop me, and I get a weird doubling of notes. Instead of a regular "dong-dong-dong" I play "da-kaa-da-kaa-da-kaa" because the bow connects twice with the violin on either side of its body. (Quartet 2018, IP4)

On the other hand, there were features of the Coretet the performers really enjoyed, and which they used along with their improvisational expertise to stretch the constraints. For example, they switched between the extreme types of Coretet instruments, using this feature to extend their supply of pitches to higher or lower regions and to expand the expressiveness of their gestures.

> We have the option to change the instrument. I switch between violin, viola or cello, which enlarges my scope of pitches. The cello I play in a really weird way, because its body is not fixed to the floor as with a normal cello. Instead I hold it like a huge oversized violin. It stretches in front of me. I use this to extend my performative movements. I want the audience to enjoy these enormous gestures, when I try to reach the end of the fingerboard of my giant cello-violin. That's fun. (Quartet 2018, IP4)

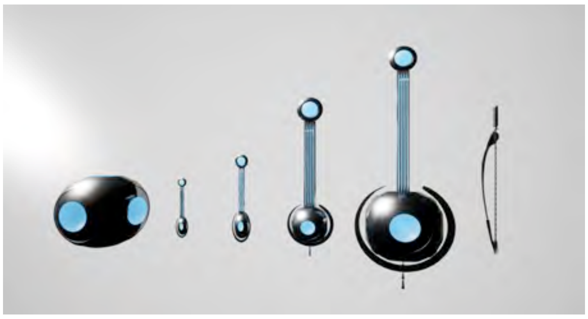

Figure 5. The Coretet family (from left to right: orb, violin, viola, violoncello, double bass, bow) © Rob Hamilton

The performative agency in Movement II of *Trois Machins de la Grâce Aimante* is strongly influenced by the playability of the interface, the virtual instrument Coretet, and the constraints given by the harmonic system and the graphical score. At the same time, however, the work builds on the performers' improvisational skills and creativeness with regard to dynamics, textures, atmospheres, and choice of instrument (the musicians were able to use the five instruments the Coretet offers to enlarge their pitch range, traversing all registers from bass to soprano). As performers, we are thus dealing with two different principles, "ludic play," which represents the rule-bound composition, and "paidic play," represented by free-form improvisational play, with ludic play constituting the predominant feature of this work.

Representational Spaces

In order to learn more about how *Trois Machins de la Grâce Aimante* engages both audience and performers and what kind of connotations the work invoked, I will now turn my attention to the two representational spaces it offers: the physical space of the concert performance, and the virtual space in which the performers move, which is only partially shared with the audience via the main performance screen. Additionally, I will trace how gadgets and aesthetics of the gaming world are tied into the composition and setup.

Hamilton states that "'gaming' influences the interaction design, control schema and overall aesthetics of the Coretet and the composition itself" (cf. the chapter "Composing (and Designing) *Trois Machins de la Grâce Aimante*"). The performers interact with their virtual instrument via the Oculus game controllers they hold in their left and right hands. They manipulate the controllers' buttons to put their fingers on the virtual finger board, to touch the strings with their virtual bow and latch onto them, or simply to change the orientation of their virtual instrument. Through their goggles, they see their instrument and the avatars of their coplayers from a first-person perspective, whereas the audience is presented with the four avatars as a stylized quartet on the main-stage screen. Images from the virtual reality spill over into the physical concert performance space.

The gestures of the musicians in the air are captured by sensors that track the location of the Oculus game controllers. The data are mapped onto virtual left-hand movements, such as shifting position, glissando, vibrato, and trills, or typical right-hand movements, such as simulating bow strokes at different speeds and in different articulations. The performers' gestures in the air are movements in the physical environment that manifest in both representational spaces: in the virtual space they make it possible to play the Coretet, while in the physical space they add to the audience's visual experience by enlarging and emphasizing performative expressiveness. Moreover, the gestures affect the sonic experience in the physical concert space.

It could be argued that the aesthetics of the Oculus Rift glasses, the laptops that are placed in front of each performer capturing the player's individual perspective on their virtual instrument, the game controllers, and the unreal way of playing transport performers and audience into the realm of computer games. However, the performers did not perceive their task as game-like, but rather like performing a piece of art:

> For me the environment is game-like, but we treated the music like serious music, in my opinion we did not include game elements. (Quartet 2018, IP3)

> The engine of this piece is built with the software "Unreal Engine 4," a really famous company which makes a lot of crazy games. So, yes, the work uses game details but it was treated in the prism of art for the purpose of making the music of the composition. (Quartet 2018, IP1)

Nevertheless, they observed that the game-like environment allowed them to break free of their usual serious inner attitude towards classical music, stating that a childlike curiosity popped up that encouraged them to be explorative. They even proposed that audience members could be offered the opportunity to try the system for themselves, perhaps in the context of a music outreach project. However, in their opinion the Coretet is a system built for experts rather than for nonprofessionals.

> Since we as string players know the possibilities of our own physical instrument, we know how to replace movements that maybe do not work [on the Coretet] … We know how to make it appear real. We bring along the knowledge of our physical instrument, the structure, movements and techniques. (Quartet 2018, IP1)

The musicians wear VR goggles that visually separate them from their audience, and they have no face-to-face contact. Nevertheless they assumed that the audience could read them through the tools they used (the game controllers and VR goggles), their body language, and the music itself: "I think we can connect, because there are the tools, there is the body present, there is the sound" (Quartet 2018, IP2).

How was the Piece Perceived by the Audience?

According to the results of the audience questionnaire, approximately two thirds of the audience members reacted positively to the piece. Many associated it with games evoked by the VR gadgets and the players' body movements that reminded them of using Wii controllers. However, they struggled with not having any direct part in the VR experience. Instead, they felt like observers unable to share the fun and almost resented it:

> I often asked myself, what do they see that I don't? How do they communicate? Do they communicate at all? … I hoped all the time that I would see something. Some kind of communication which would let me share the excitement, like "Hey, do something together!" … Almost all the time I felt that I was just an observer, since I had no chance to intervene. I even thought, I would love to just go there and tell them: this thing, why don't you just take it and just play for yourself, please, don't make such of show of it! (Focusgroup_1 2018, IP1)[4]

> I often drive racing simulators with VR glasses myself and that is fun as long as you drive yourself …. I don't think it's as fun as an observer as someone who really does it. (Focusgroup_1 2018, IP2)[5]

However, there were moments when audience members were able to relate to the piece through their prior knowledge of similar situations. In our audience questionnaire, many mentioned associations with games such as *Guitar Hero*, Nintendo Wii sports or music games, and interactive games they were familiar with from their PlayStation. This notion was picked up in our focus group interview: "This reminds me of the Wii controller which you have to fidget around with, and you also do it with a group of people" (Focusgroup_1 2018, IP2).[6] Others felt involved when watching the musicians' chamber-music interactions:

> I felt drawn in when I had the feeling now the four are synched, they make music together. Most of the time it felt like each of them was moving independently, but in these moments, mostly when they played fast, it gave me the impression that they harmonized, those were the moments when I felt more involved …. For me this was not an effect of gaming, but actually, I found it highly aesthetic and participative. (Focusgroup_2 2018, IP4)[7]

Space of Possibility

To us performers, *Trois Machins de la Grâce Aimante* was a concert piece first and foremost. Musically, we found controlling our musical interface, the Coretet, challenging, but we saw potential in it, even if we did not entirely agree with the composer's claim that the virtual instrument could be used similarly to an ordinary physical string instrument. We felt that the space of possibility the Coretet offered was—at least in its prototype version—still rather restricted, and we were aiming for something that was (yet) out of reach. Instead of mainly being steered towards the past tradition of playing string instruments, we would have equally liked to explore the instrument's potential especially with regard to its future-oriented aspects. Therefore, I would like to raise a set of follow-up questions: what does the Coretet offer that the physical string instruments cannot? How can we use these qualities in our performance? Is there an alternative to the way game aesthetics in *Trois Machins de la Grâce Aimante* could be employed to emphasize a ludified approach or involve the audience? Would any of this increase the agency for the players and offer a richer space of possibility that in consequence would result in more meaningful playing?

What does the Coretet offer that classical string instruments cannot? The Coretet encompasses the whole family of string instruments, from the double bass to the violin, and includes the so-called "orb," which is meant to be used as a percussion instrument (see figure 5). Moreover, although the Coretet's sound is based on the physical model of a string, it does not sound like any ordinary string instrument. Hamilton describes its sound as abrasive, distorted in certain ranges, and noisy. What does this mean for the musical agency of the performers? The wide instrumental range—orb, violin, viola, violoncello and double bass—that is accessible simply by pressing a button on the right-hand controller gives the player extra scope in terms of sound color, pitch range and gestural play. The Coretet's extraordinary sound world should be explored for its uniqueness, instead of modelling the playing on the sound world of the classical string instruments, as it was suggested we do. There are different shades of noise and sound colors to be revealed, its abrasiveness and distortedness to be explored musically, and the percussive qualities of the orb to be discovered.

The virtual instrument Coretet lacks the physicality of an instrument. Instead of holding the body of their instrument, gripping a fingerboard, and bowing strings, the musicians move their arms through the air while emulating playing a physical string instrument. This emphasizes gestural play. As a theatrical tool or means of expression, it adds to the performative agency of the musicians and their feeling of meaningfulness. To give an example: by switching through the different sizes of the Coretet, performers can vary the size of their gestures in quick sequence, changing from the tiniest of movements when playing the smallest instrument of the family, the violin, to huge ones when playing the orb or the double bass. The latter is especially effective if the bass is held like a giant violin instead of playing it in its ordinary upright position. The gestures are stretched out and exaggerated, the musician might even have to get up from their chair, adding a dramatic element to a possibly wild musical atmosphere (see figure 6).

Figure 6. The image shows the gestural play of one performer who is standing up to reach the end of the fingerboard of her oversized Coretet. © ndbewegtbild

The performers can use gestural play as a method of conveying musical meaning. At the premiere, for instance, the musicians had to lock in a regular steady pulse led by the cellist. The musician played discreetly, the rhythm was almost unnoticeable in her movements. By clearly articulating and demarcating her gestures when playing, she could have taken the audience along with her by using her physical movements to illustrate how sound is produced in the invisible virtual space and then sonically projected into the physical concert space, thus making it easier for the public to understand the music, the technological setup and the musical scene.

Another aspect of *Trois Machins de la Grâce Aimante* that merits further exploration is its cinematographic quality. The audience are able to watch five screens in total: the large main screen at the back of the stage as well as four laptops, each assigned to one performer, sitting on a table vis-à-vis the instrumentalists. These individual computer screens show what each performer sees in the virtual space, thus offering the audience a glimpse of the performers' first-person perspective on their instruments, which otherwise is hidden behind the VR glasses. Not everybody understood the connection:

> Since there were five screens in total, I could not really feel my way into the piece, because I always jumped from one screen to next and wondered, what's the purpose of the screen? What's happening here? … I would have found it more invasive if there had been one large screen with four split screens on which I see every screen in one. (Focusgroup_2 2018, IP3)[8]

Accordingly, how can a connection be established between the individual actions of each performer, what they see, and the way it is staged? Larger gestures could convey musical meaning to the audience. If these gestures were coupled with a video projection of what the acting individual performer was seeing at that moment in the virtual space, their visual experience could be shared with everybody on the main-stage screen. Depending on the musical development, individual screens that show the instrumentalist's perspective could occasionally be brought to the foreground, alternating with the virtual, white performance space in which the four players are depicted as avatars. This would be particularly effective in combination with solo passages or distinct musical patterns that can clearly be assigned to one individual player.

In this way, everything would come together in the physical world of the performance space, the sonic result, the performers with their physical gestures on stage, and their visual representation on the main-stage screen. Going to an extreme, the role of director of visuals who features players' projections on the main screen could even be assigned to individual audience members in a participative setting. Ultimately, this could result in a dramaturgical setting in which musical structure, gestural play, and choice of the video screened add to the cinematographic experience for players and audience alike.

I hypothesize that by shifting the conceptional compositional focus from imitating traditional classical instruments to the unique features of the Coretet and the special staging of *Trois Machins de la Grâce Aimante*, the musicians would gain more musical and performative agency and meaningfulness in their explorative creative actions; additionally, the audience would gain more direct access to the virtual world of the Coretet, which again might counterbalance the feeling of being left out and emotional distance that some of our visitors described.

In addition, one performer suggested that the Coretet could be employed as an educative tool in audience outreach in participative settings in which audience members are allowed to play and explore the instrument. Another performer thought the instrument had even further artistic and social potential:

> Let's say we look a bit further into the future. In my opinion, in maybe fifteen or twenty years from now it will be possible for people from different parts of the planet to play in some kind of international virtual reality online jam session, similar to the way that they connect with each other to play games all night today. An improvisation session for which they can just sit in their home, put on their VR glasses, get connected with each other and make music. Just like that. That would be really great. Well, I think this project is one of the greatest examples of how we can use technology and virtual reality for us, for the future and especially for art. I am sure it will have really big resonance in the future and will serve a good purpose: for art and for the next generation. (Quartet 2018, IP1)

In the following case study, *Terrain Studies* by Christof Ressi, I investigate how the virtual space the performer moves in and the actual physical performance space are connected and shared between audience and performer and in which way the interplay of both influences the experience of the work.

Case study 2: Christof Ressi's *Terrain Study*

Christof Ressi's *Terrain Study* is an audiovisual composition for solo instrumentalist and virtual reality system conceptualized as a ludified 3D performance environment that takes place in both virtual and physical space. "The situation is that of a classic first-person game. There is the camera that is linked to the player's field of vision. It is … a classic VR game where one moves in a [virtual] environment" (Ressi 2018).[9] The instrumentalist wears a VR headset (model HTC-VIVE) and experiences the performance exclusively in the virtual 3D environment, whereas the audience follows the projection of the player's VR perspective on a screen placed on the main stage, where the performer is also physically present in the center of attention.

The performer's tasks encompass the creation of the entire sound world—there are no preproduced or synthesized sounds—and the visual manipulation of the initial landscape, the visual and sonic interaction with objects that appear, the so-called 'orbs' (see figure 7), and last but not least the enactment of a performative scene on the physical stage. The landscape and the musical and bodily interaction with it become the performer's creative interface.

> Actually, this landscape is an instrument. You have these orbs which you can interact with and which record your sounds .… One's own behavior in the space influences the sound, in fact more and more so in the course of the game. And then slowly, this transfers to the landscape itself … Whatever you do—soundwise or with your head [the head movement is tracked via the VIVE]—is translated into parameters that eventually deform the environment more and more. (Ressi 2018)[10]

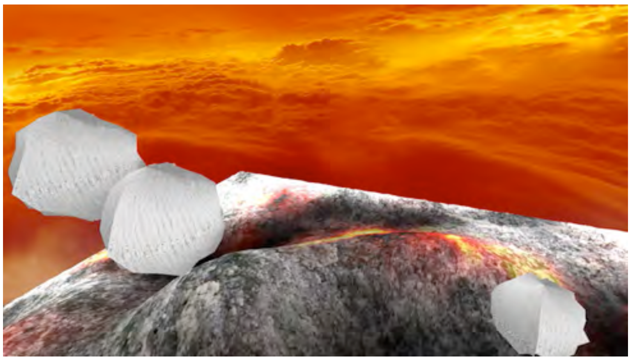

Figure 7. Screenshot of *Terrain Studies* showing the landscape with hovering orbs. © ndbewegtbild

In the beginning, the instrumentalist tentatively explores the virtual landscape by improvising. Soon she encounters flying orbs, which invite playful interaction. Whenever the performer touches one of the orbs, they briefly turn red, which signifies that they are now recording the sound produced by the performer. Having finished recording, they start to pulsate and play back the recorded sound while circling around the player. Soon the orbs float away into the landscape, thereby modifying the sonic characteristics of the looping sound. The orbs' own movement in the landscape and the (computer-tracked) movement of the performer's head both influence the sound processing. If the orbs descend towards the ground, the pitch of the recorded sample becomes gradually lower, and if they rise into the sky, the pitch rises as well. Likewise, if the performer raises her head, a delay sets in that is spread across the ambisonic loudspeaker system. Over the course of the piece, the performer is increasingly amplified and blends into the overall level of dynamics, which according to the composer subtly suggests that she is becoming more and more part of the artificial environment. Gradually the performer's presence in the landscape and influence on the environment grows. This is not limited to the sonic world, but has visual consequences as well.

> The first thing that happens is that an orb floats towards me. If I approach the orb closely enough, it turns red, which is the moment when I can play for it. So what I'm playing right now is recorded and stays in the orb. It then starts to pulsate and reproduces my sound in a loop, which is immediately modified. It is pitched up or down, mostly sounds a bit rougher, not anymore as I recorded it myself. And the pulse, the delay, can also change. This can sometimes be faster, sometimes slower. The volume also changes depending on how far the orb is away from me. And soon a second orb will be added. And a third. And a

> fourth. I can always fill them with different sounds. One can also stop an orb by approaching it again until it turns red, and if you then don't play, you fill it with silence, and the sound stops. (Lüneburg 2018c)

In the virtual world, the player stands on a square island that starts out as an artificial plain surrounded by water. As soon as the performer plays her first note, the topology immediately begins to react to her sonic input and body movements, slowly changing into a hilly island, turning into a volcano, a desert or a mountain formation. The audience is able to follow the performer's movements in the virtual 3D landscapes on the main-stage screen. Behind her VR glasses she needs to climb steep hills, cross ravines and interact with the floating orbs. In the real world, however, the instrumentalist is plainly standing on the floor of the stage within a marked-off square and the audience sees her move within these boundaries.

> First it gets hilly, then there are very, very high mountain peaks and extremely deep gorges, and as a performer I have to go through this landscape again and again. This is sometimes uncomfortable because I have the physical feeling that I am really in a real landscape, that is, one step further and I fall down the slope. Of course, this is not the case in reality, because you always move on the level stage. (Lüneburg 2018c)

The audience takes the role of backseat gamers gathered around the 'skillful player,' who negotiates the difficult terrain, interacts with the obstacles thrown in her path, and at the same time composes the music.

> The audience always sees the landscape from my perspective. When I turn my head while playing, the stage screen also shows the section of the area I'm looking at right now. (Lüneburg 2018c)

Moreover, via the spatial arrangement of the audio rendition, performer and audience share what game theoretician Gordon Calleja calls a "a sense of habitation within the game environment" (Calleja 2011, p. 75). What the performer hears within her VR headset and the angle from where a sound source reaches the performer in the virtual world is mapped onto the ambisonic loudspeaker system of the performance space. In this way, the performer has real-time control over the audience's listening situation. However, this mapping results in a different sonic experience for the audience than for the player, since the instrumentalist is continuously changing her position in the landscape, whereas the audience is sitting completely still, facing in a single direction only. For the instrumentalist the sounds remain stable and naturally related to her movements and her viewing direction, whereas each of her head movements causes a dramatic shift in the spatial placement of sounds for the audience.

Over the course of the piece, the sounds and landscape undergo more and more electronic processing, which again is controlled by the movements of the player. Ressi explains that the virtual world and the player become one:

> In principle, my position in the space and my head orientation allow me to shape the sound … which then slowly changes to the landscape itself, which is then deformed more and more. ... In the end there is almost a situation where the space no longer exists without the violin. There is a point where the violin needs to maintain this space entirely. And when she plays certain things, the world is completely broken. It is actually a shift from 'I am a part in this room' to 'I am the room.' (Ressi 2018)[11]

Since the performer's body movements are tracked and influence the visual and sonic scene in multiple ways, her physical presence on stage becomes as important as her music playing. Respondents to the audience questionnaire mention that the choreography of movements and the performer's stage presence has a clear impact on their experience of the music and the cinematography on the video screen. They mentioned, for instance, that game and performance melt into one. Ideally the player uses this feature to create a situation on the actual performance stage that gesturally underlines what is happening in the virtual scene and is at the same time expressive on the physical stage as well.

Applying the Polar Diagram to Terrain Studies

The interface axis for *Terrain Studies* reflects the use of an interface that requires a lot of expertise while also being very responsive. The entire virtual reality system, including the 3D performance environment and the physical environment of the concert space, serves as an integral interface. The proficiency needed encompasses instrumental improvisational skills and an understanding of the action-reaction response offered by the interactive elements of the landscape and its actants, such as the orbs. In addition, conceptual thinking is required to perform the work, such as foresight into the formal and cinematographic development of the piece. The work furthermore requires physical presence and an understanding of how gestural play conveys meaning to the audience.

Once performers have familiarized themselves with *Terrain Studies*, the interactive system makes relatively predictable planning possible. However, on both sides of the determinism axis the mark is only in the middle, since in performance situations the composer himself likes to come up with surprising new interactive features that call for spontaneous reactions and flexibility from the performer: sudden teleporting or self-destruction mechanisms that have not been introduced in the rehearsal or novel actants in the form of further interactive objects will create an unfamiliar, challenging situation for the instrumentalist.

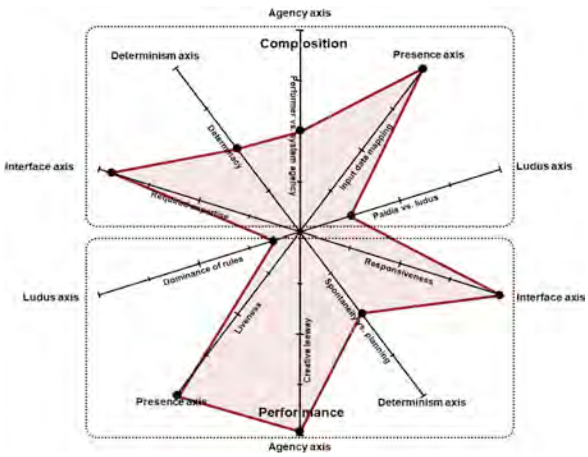

Figure 8. Polar diagram for Christof Ressi's *Terrain Studies.*

The mark for the "performer vs. system agency" axis lies in the middle, corresponding to the fact that the performer is presented with an interactive environment and tasks that are both carefully conceptualized. At the same time, the performer's input is required to shape the scenery in both musical and visual terms. The performer's stage presence is important and conducive for the audience's experience. Every action of the performer is meaningful and its short-term and long-term results can be observed by both player and audience. The performer literally shapes the landscape, the music, and the cinematographic scene and constructs the overall form of the performance. Accordingly, the creative leeway given to the performer is marked as very high.

The marks on the presence axis show that audio input and movement data mapping are essential for *Terrain Studies*. The feeling of "liveness" on the performer's side corresponds with this and is also perceived by the audience. One interviewee remarked: "The reaction between the musician and the visual effects and sound was really fast and just good" (Focusgroup_2 2018, IP2). The ludus axis indicates a minimum of rules, which were indeed rather general explanations about how the player's improvisation and movements would influence the system and what to do first: catch a flying orb and fill it with a sound, then watch what happens and react to it. *Terrain Studies* supports paidic play, and exploration and improvisation stand at the foreground of the player's experience

How was the Piece Received by the Audience?

More than 90% of the respondents to the questionnaire stated that the game aspect of the performance of *Terrain Studies* was of central importance to them. This was brought up by the interviewees in the focus group as well: "With the virtual there is of course already an association of play through the performer" (Focusgroup_1 2018, IP4).[12] However, they did not feel like backseat players: "Through these balls that come towards you ... you have the feeling that you are more in the middle of it. But really as a backseat player? No, not at all!" (Focusgroup_1 2018, IP3).[13] According to the questionnaire, many felt drawn in by the coalescence of the visual, performative, and sonic elements triggered through the performer's interaction with the orbs and landscape in the virtual environment.

> With Ressi I thought it came across pretty well through the visual and auditory level that these orbs were activated. Because they were so distorted and then sounded themselves. It was actually immediately clear that she would go there and record something, then the orb would replay it. (Focusgroup_2 2018, IP3)[14]

> I think that was an essential principle, ... that you could follow the eyes of the performer. To put myself in her position definitely works better this way! (Focusgroup_2 2018, IP1)[15]

Sounds and visuals typical of computer games, cultural references to well-known game types (such as sports games using Wii controllers), and the use of interfaces that are typical for games (such as the VR headsets or game controllers) underline the impression of a game-related artwork. One interviewee observed: "I mostly found a connection between game, art, and music on the visual level. For me, the game level is always the visual one. Be it the image or the performative physical level" (Focusgroup_1 2018, IP4).[17]

The game aspect of the works was able to facilitate spectators' access to the aesthetics of the artwork or at least help them to cope with the work's 'weirdness': "I think that it won't work without these gaming elements because it is actually weird to listen to for most people. It is very, very weird music" (Focusgroup_1 2018, IP2).[18] Nevertheless, the game aspect does not guarantee the inner involvement of the audience: "It is very important for me to say that I was only there as an observer and that it would probably be quite different if I did it myself" (Focusgroup_1 2018, IP1).[19] Last but not least, a lack of observable and comprehensible game mechanics, such as rules and goals, can throw the audience off: "For me, the gaming character was gone immediately when I saw no goal of the whole. Why do you do that now? What is the motivation behind it?" (Focusgroup_1 2018, IP1).[20]

To conclude, I investigate which kind of agency and meaningfulness is created through the fusion of virtual reality and physical reality in the representation of an artwork. How does the given setup aesthetically and performatively impact the work of the performer and the audience's perception? What influence does it have on the player's ludic and performative involvement? What could a space of possibility look like that furthers the performer's creative range of expression in both the physical space of a concert performance and the virtual space beyond the VR glasses?

Although according to the questionnaire most members of the audience experienced *Terrain Studies* as positive, they also described it as dystopian, nightmarish or overwhelming, and for some it bordered on 'too much': "Occasionally I looked away because there were a lot of impressions at once, and that was almost a bit overwhelming, actually" (Focusgroup_1 2018, IP3).[16]

Conclusion

Conditions for Involvement

The performers measured Hamilton's virtual instrument Coretet and the agency it provided them against their traditional physical instrument and missed the reliability and flexibility offered by the latter. They felt they needed this reliability and flexibility for their musical playing and that their musical and performative decision making was at least partially impeded by it. I claim that concentrating instead on the instrument's cinematographic and gestural as well as performative potential could considerably increase both the performers' agency and the audience's involvement. In my opinion, this would allow for a different kind of performative and musical action and creative decision making "that let performers transmit the artistic experience on a social and artistic-communicative level in cognitive, sensor-motoric or emotional ways" (Lüneburg 2018a).

Ressi aims at building a system in which performer and audience and the virtual realm and physical concert space are tightly intertwined. Actions and gestures in the physical space have clearly discernable artistic results in the virtual space. The concert space's technological and stage setup translates these actions and results to the audience in an understandable way, thereby strengthening involvement and the feeling of meaningfulness for both player and audience members. This could be observed in the performer and focus group interviews and the audience questionnaires from the lab concerts.

Tacit Knowledge

Tacit knowledge helps audience members to relate to a performer's ludic or performative actions and to identify with the person or the situation. Moreover, it furthers the inner involvement of the observing audience members. As the sociologist Stephen Turner suggests, tacit knowledge of an activity allows for better understanding and communication: "Some activity, inference, or communicative act depends on both the user and the recipient possessing some inferential element or mechanism which allows them to understand, anticipate, co-operate, or co-ordinate with another" (Turner 2014, p. 155). In Hamilton's work, audience members were able to relate to the VR experience and use of game controllers mostly via their personal playing of sports, dance, or racing games and musical games such as *Guitar Hero*. Ressi's work seemed to speak to them through their knowledge of and experience with open-world games and first-person games.

Hamilton states that "an understanding of the interconnected nature of any human-occupied virtual space with our own physical world" has informed his artistic endeavour with the Coretet (cf. the chapter "Composing (and Designing) *Trois Machins de la Grâce Aimante*"). The same notion has guided my investigation of both Hamilton's and Ressi's works. I found two fundamentally different approaches to dealing with virtual reality. Hamilton chose to convert a physical instrument into the virtual idea of one. He focused on the development of an instrument for a new environment that emulates a traditional one and takes it beyond pre-conceived instrumental boundaries. Ressi, by contrast, invented a virtual environment that is manipulated and shaped with the help of an 'ordinary' instrument and the player's body movements in the physical world. What unites both works is that actions in one reality have an impact on the other. However, the two composers pursued different artistic goals.

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Focusgroup_2. Interview by Andreas Pirchner with the participants of focus group 2 in the framework of the GAPPP lab concert at the the Institut für Elektronische Musik und Akustik's Cube in Graz (Austria) on September 27, 2018

Hamilton, Rob. Interview by Andreas Pirchner with composer Rob Hamilton on his work *Trois Machins de la Grâce Aimante* within the framework of *GAPPP – Gamified Audiovisual Performance and Performance Practice*. Interview conducted on July 29, 2018.

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Quartet. Interview by Barbara Lüneburg with the performers of Hamilton's string quartet in the framework of the GAPPP lab concert at the Institut für Elektronische Musik und Akustik's Cube in Graz (Austria) on September 27, 2018.

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Notes

1 Continuing my research in "Between 'Ludic Play' and 'Performative Involvement'," *eContact!* 202 (2018), and "Between Art and Game: Performance Practice in the Gamified Audiovisual Artworks of GAPPP," *The Computer Games Journal* 7 (2018), pp. 243–260.

2 In my paper "Between 'Ludic Play' and 'Performative Involvement'," I discuss the GAPPP works *Tonify* (2017) by Martina Menegon/Stefano D'Alessio, *Kilgore* (2017–18) by Marko Ciciliani, and *game_over_1.0.0* (2017) by Christof Ressi. In "Between Art and Game: Performance Practice in the Gamified Audiovisual Artworks of GAPPP," I investigate *Attractive Correlations* (2017) by Kosmas Giannoutakis and Simon Katan's *Conditional Love* (2016). The abovementioned works by Ressi, Ciciliani, and Giannoutakis are documented on the USB stick included with this volume.

3 At that time, of the three movements of *Trois Machins de la Grâce Aimante*, only Movement II had been finalized and accordingly was the only one to be premiered by the musicians.

4 Orig.: "Ich habe mich oft gefragt, was sehen die, was ich nicht sehe? Wie kommunizieren die? Kommunizieren die überhaupt miteinander? ... Ich habe die ganze Zeit darauf gehofft, dass ich was sehe. Irgendeine Art von Kommunikation, die mich auch ein bisschen mitfiebern lässt, so was von 'Macht's doch mal was zam!' … Ich habe mich eigentlich fast immer nur als Beobachter gefühlt, weil ich auch nicht eingreifen konnte. Ich hab schon gedacht, ich würde am liebsten hingehen und sagen: dieses Ding da, leg's dir doch einfach hin und spiel schön damit, und zeig's nicht so her."

5 Orig.: "Ich fahre selber öfters mal Rennsimulator mit VR-Brillen und das macht halt Spaß solang man selbst fahrt. Und sonst glaub ich ist das als Beobachter nicht so lustig, wie als jemand der das wirklich performt."

6 Orig.: "Das hat etwas von Wii spielen, wo man so herumfuchteln muss, und man das auch mit mehreren Leuten macht."

7 Orig.: "Ich habe mich dort hineingezogen gefühlt, wo ich das Gefühl gehabt habe, die vier sind jetzt aufeinander abgestimmt, musizieren. Meistens hat es sich für mich so angefühlt, als würde jeder sich für sich bewegen. Aber ganz kurz, vor allem wenn sie sich ganz schnell bewegt haben, hat es dann so gewirkt als wären sie aufeinander abgestimmt. Und das waren dann diese Momente, wo ich mich mehr involviert gefühlt habe. ... Für mich war das kein Effekt vom Gaming, sondern hoch ästhetisierend und partizipativ, eigentlich."

8 Orig.: "Dadurch dass es insgesamt fünf Bildschirme gab, hab ich mich nicht so richtig reinfühlen können, weil ich immer von einem zum anderen gesprungen bin und mir gedacht hab, was macht der Bildschirm? Was passiert da? … Ich hätte es invasiver gefunden, wenn ich einen großen Bildschirm gehabt hätte mit vier Splitscreens, wo ich dann die vier Bildschirme auf einem sehe."

9 Orig.: "Die Situation ist die eines klassischen First-Person-Games. Es gibt die Kamera, die eigentlich an das Blickfeld des Spielers gekoppelt ist. Es ist … ein klassisches VR-Game, wo man sich in einem [virtuellen] Raum bewegen kann."

10 Orig.: "Eigentlich ist diese Landschaft ein Instrument. Man hat diese Kugeln, mit denen man interagieren kann und die deine Sounds aufnehmen ... Das eigene Verhalten im Raum beeinflusst den Klang, und zwar im Laufe des Stücks immer mehr. Und dann geht es langsam auch auf die Landschaft selbst über .... das was man klanglich oder mit dem Kopf macht [die Kopfbewegungen werden über die VIVE wird getrackt, Anmerkung der Autorin], wird in Parameter übertragen, die die Landschaft mehr und mehr deformieren."

11 Orig.: "Im Prinzip ist es so, dass ich durch meine Position im Raum und durch meine Kopf-Orientierung den Klang gestalten kann, … was dann langsam auf die Landschaft selbst übergeht, die dann dadurch mehr und mehr deformiert wird .... Am Ende gibt es fast eine Situation, wo der Raum ohne die Geige überhaupt nicht mehr existiert. Es gibt einen Punkt, wo die Geige schauen muss, diesen Raum überhaupt aufrecht zu erhalten. Und wenn sie gewisse Sachen spielt, ist die Welt komplett kaputt. Eigentlich ist es eine Verlagerung von 'Ich bin ein Teil in diesem Raum' hin zu 'Ich bin der Raum.'"

12 Orig.: "Mit dem Virtuellen gibt es natürlich schon durch die Performerin die Assoziation von Spiel."

13 Orig.: "Durch diese Bälle die dann auf einen zugekommen, ... hat man das Gefühl, man ist mehr mitten drin, aber so richtig als Mitspieler, nein das gar nicht."

14 Orig.: "Bei Ressi fand ich, kam es durch die visuelle, und auditive Ebene ziemlich gut rüber, dass man diese Kugeln aktiviert. Dadurch dass sie so verzerrt wurden und dann selbst geklungen haben, war eigentlich sofort klar, sie geht da jetzt hin und spielt was ein—dann spielt die Kugel das nach."

15 Orig.: "Ich glaube das war schon ein wesentliches Prinzip, dass man den Blicken der Performerin folgen konnte. Das Reinversetzen ist so definitiv besser!"

16 Orig.: "Teilweise habe ich beim letzten zwischendurch weggeschaut, weil es sehr viele Eindrücke auf einmal waren, und das fast ein bisschen überfordernd war, eigentlich."

17 Orig.: "Also einen Zusammenhang von Game, Art und Musik habe ich am meisten auf der visuellen Ebene gefunden. Die Game-Ebene ist für mich immer die visuelle. Sei es die Bildebene oder die performative körperliche Ebene."

18 Orig.: "Ich glaub' dass das ohne diese Gaming-Elemente nicht so funktioniert weil es eigentlich für die meisten Menschen schräg anzuhören ist. Es ist halt sehr, sehr schräge Musik."

19 Orig.: "Für mich ist es sehr wichtig zu sagen, dass ich nur als Beobachter dabei war, und dass es wahrscheinlich etwas ganz anderes wäre, wenn ich das selbst machen würde."

20 Orig.: "Für mich war der Gaming-Charakter sofort weg, wenn ich kein Ziel gesehen habe von dem Ganzen, wieso man das jetzt macht. Welche Motivation steckt dahinter?"