Gerhard Nierhaus *Editor*

Patterns of Intuition

Musical Creativity in the Light of Algorithmic Composition

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Contents

Introduction

Gerhard Nierhaus

'Give a sequence of six numbers by choosing randomly from 1, 2 or 3!'—Most people would respond to this task with number sequences such as the following: '1 2 3 2 3 1', '2 3 2 1 3 1', '3 3 2 1 1 3', '1 2 1 1 3 2', '1 3 1 2 2 3'. The character of the sequences given would not be essentially different if the task were slightly varied in sequence length or quantity of numbers to choose from.

One may now ask whether there are any commonalities to such sequences, and whether there are any latent rules at work during their forming, rules as yet unknown. In approaching an answer to this question, one might transfer the task to a computer program. Within the sequences produced by the program there will occasionally be ones such as '1 1 1 1 3 1' or '1 3 1 3 1 3', or ones like '2 2 2 2 2 2' or '1 2 3 1 2 3'. Such will however only appear exceptionally in the sequences generated by humans.[1] Notions (in themselves formally correct or incorrect) and strategies (used intentionally, or, in other cases, automatically or unconsciously) for a 'random selection' differ between individuals.

Hypothetically, and in order to gain some insight into the structure of those humanly generated sequences, the following "rule of thumb" can be applied to the making of such sequences: 'When forming a sequence, strive to use all numbers, and seek to avoid obvious patterns'. A next step would aim at a formally correct representation of this "rule",[2] in turn followed by implementing a software capable of producing such sequences. A user evaluation could then deliver clues as to the adequacy of the hypothesis that the structure of the human generated sequences can be approximated by the formalised rule of thumb.

[1] Whenever such sequences are found they will arguably stem from someone with a background in statistics, who has reflected on the task and probably possesses a good sense of humour.

[2] The criterion 'seek to avoid obvious patterns' already raises a number of tricky and interesting questions to the task.

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Such and similar were the thoughts that—transferred to the domain of music—led me to initiate a project in which some aspects of composition are viewed from a different perspective by means of algorithmic composition. I envisaged a kind of musical analysis that begins with the composers' structural ideas and, by way of a dialogical process, makes the ideas visible on a more objectifiable plane.

The present book is a result of a three year research project (*Patterns of Intuition*, funded by the Austrian Science Fund (FWF), project number: AR-79), in which my colleagues Daniel Mayer, Hanns Holger Rutz and myself stood in a creative dialogue with numerous composers, seeking to trace important facets of their respective individual compositional approaches. In all this, the composers themselves chose a point of departure, where upon we focused on researching a specific aspect or compositional principle, proceeding thereafter in a dialogical manner with the artists. Generally, the procedure was thus:

Presentation of a compositional principle. Formalisation of the approach and implementation in the form of a computer program. Computer generation of musical material. Evaluation of the results by the composer. Modification of the strategy of formalisation with respect to the identified objections. Entry into new and further cycles of generation and evaluation until correlation between the computer generated results and the composers' aesthetic preferences is sufficiently high, or the limits of formalisation have been reached (which might be the case for various reasons). As indicated by the latter limits of formalisation, compositional decisions beyond this point are reached intuitively, and are thus outside the reach of a meta level representation.

The project Patterns of Intuition was therefore not aimed at addressing musical intuition as a whole in completely formalisable terms; rather, the project aim was to shed light on those particular aspects of intuitively made decisions that can be related back to implicit rules or constraints applied by the composer.

One example of such a process is the collaboration with composer Clemens Nachtmann. Nachtmann's work is led by his avoidance of tonal associations. In his case we wrote a program which works ex negativo so to speak: 'everything is possible, but!' Concentrating on chords, we at first formulated simple constraints to exclude pitch constellations with associations of tonality. We then presented diverse instances of generated chords to Nachtmann, which he then evaluated. After a number of cycles through which we followed his observations and critical comments we arrived at a dense web of constraining conditions, which in the end selected only 14 chords (from a vast number) that would ruffle no feathers if used within an 'orthodox' new music context.

In a case such as this, a traditional score analysis would not have been able to deliver a full description of all harmonic constraints underlying the forming of such chords, since it can only rely on exemplificatory materials. At the same time it is clear that the results of analyses coming from this and similar projects within POINT are not cast in stone—we are dealing with snapshots from a compositional process, often within the context of a single piece, during the course of which structures most often undergo further changes and transformations. Nachtmann himself has commented pointedly on this and other aspects of his project contribution.

The basic approach of the project, with its generative and evaluative cycles, obviously describes an idealised model. Clearly, within the framework of such processes there appear numerous side effects, which feed back into the results of the analyses. To give some examples: composers are generally unfamiliar with a situation in which they discuss their compositional work during its origination and, at same time, evaluate generated structures with respect to their own goals. Besides, the criteria for evaluation can change during the course of such a process, even those referring to their own work, so that it can seem appealing not only to analytically observe the results of what was computationally generated, but to introduce them into the ongoing creative process. In broad allusion to quantum mechanics one might say that the observation changes the outcome.

In each case of collaboration with the composers the approach taken was markedly different, and it did not follow the described cycles of generation and evaluation in every case. The same diversity was present in the individual compositional practices and aesthetic positions of the composers. There were a large range of different approaches, starting from Elisabeth Harnik's working with improvisational structures, through the attempt of an automatic classification of personal preferences in the case of Matthias Sköld, to Bart Vanhecke's and Peter Lackner's work with interval- and tone-rows.

Structural Overview

In the first part of the book—*Composers' Projects*—each chapter describes the collaboration with a composer. The chapters begin with a presentation of the composer's artistic background. This is followed by sections called *Artistic Approach* and *Exploring a Compositional Process*, concluding with a *Project Review*. Each *Artistic Approach* section features the composers' discussions in relation to the following topic areas: (1) Statement: A concise description of their personal aesthetic position and their compositional approach; (2) Personal aesthetics: This concerns details of individual practices; (3) Formalisation and intuition: The composer's views on the field of tension between formalisation and intuition; (4) Evaluation and self-reflection: How each composer appraises and conceives the results of her or his work; (5) Project expectations: Insights the composer hopes to gain through work on the project.

The section *Exploring a Compositional Process* describes the collaboration between composer and project team.

The section *Project Review* is dedicated to composers' discussions of the outcomes of the collaboration, considering especially whether it led them towards new insights on their own compositional process.

Regarding the chapter contents: Next to being a composer, **Elisabeth Harnik** is a well known piano improviser. In her project, she sought to understand some of the stylistic choices she makes in her chosen musical constellations. For this, we

recorded improvisations and generated new ones using prefix- and suffix-trees within a variety of context based methods.

Clemens Nachtmann's aesthetics avoids tonal associations. Together with the composer we arrived at a system by which we computationally determined significant criteria matching Nachtmann's choice of chord materials and aesthetic practice and verified by Nachtmann in various stages of evaluations. The system combines a method of exclusion with complete enumeration of all solutions.

Eva Reiter took sounds she recorded from a range of machines as a point of inspiration for a string quartet. The research collaboration addressed potential correlations between the original audio files and the finished quartet on the level of the sounding structure.

A part of **Clemens Gadenstätter's** work is based on a complex system of intertwined metaphoric expressions. We aimed at modelling this network of relations by way of a generative grammar, and to compare possible derivations of the system with the solutions he arrived at himself. Aspects of weak synesthesia and metaphor theory are of further relevance to Gadenstätter's work. **Thomas Eder** contributed a linguistic perspective to the composer's research.

Interlocking musical patterns and polyrhythmic structures are among the characteristics of **Dimitri Papageorgiou's** compositional practice. In this project we formalised these techniques, after which Papageorgiou showed how these formalisations apply within the context of a number of his compositions.

Transitions between harmonic fields are important to **Katharina Klement's** work. The aim was to find specific principles for strategies of morphing to approximate her handcrafted transitions.

Orestis Toufektsis at times works with harmonic processes, shaping them more or less intuitively. Based on genetic algorithms, we developed a system which enabled Toufektsis to generate different chord sequences. He then evaluated these chord sequences as to their compositional adequacy under different criteria. Seeking to keep the evaluation criteria flexible and to provoke surprising solutions, a human fitness rating was used rather than an algorithmic fitness function.

Alexander Stankovski works with a technique he calls 'mirroring', a technique not dissimilar to a use of palindromes. Stankovski's technique involves a conscious variation of nesting mirrors within mirrors, and also applying the mirroring procedure to different musical parameters.

With **Mattias Sköld** we investigated whether machine learning might assist our understanding of what makes musical structures 'interesting' rather than 'uninteresting'.

Djuro Zivkovic often works with chord sequences created from combinations of difference tones. We implemented his approach in various ways and compared the results with Zivkovic's handwritten solutions.

Bart Vanhecke uses 54-tone interval-rows as a basis for compositional elaboration; central to the present project was the question whether "optimal" rows computed via brute force procedures would be of additional compositional value when compared to those rows already considered optimal by the composer.

Peter Lackner's practice features an innovative approach to the systematisation of 12-tone rows. In the second section of this chapter this systematisation is presented in terms of mathematical music theory by mathematician **Harald Fripertinger** in collaboration with the composer.

Interdisciplinary Contributions

The collaborations with the composers should also to be viewed within the context of different disciplines. Given the involvement of creative processes, this project can certainly be conceived as a form of artistic research, while at the same time the analytical focus situates it into a musicological context. Beyond this, the kinds of methods used also make this project an undertaking in algorithmic composition. The underlying methodology—namely the working through of cycles of generation and evaluation—characterises the project as experimental and last but not least, the project's results open up discourses which can be oriented according to a variety of different perspectives. In order to look "outside the box", so to speak, a number of outstanding researchers (who are, in part, active as artists also) were invited to respond to the project and its outcomes informed by their different perspectives; to offer independent contributions on the topic or, alternatively, more general views from their respective research fields.

Regarding the chapter contents: **Darla Crispin** reflects upon the contemporary status of composition both as an artistic and as an academic practice, as seen from the perspective of artistic research. She speculates on how some of the creative listening practices described by composers within the POINT project might help to revivify the relationship between sound, structure and meaning which lies at the heart of a healthy compositional tradition.

William Brooks situates the POINT project in the context of experimental practice in music, especially in the tradition of pragmatist aesthetics initiated by John Dewey.

Nicolas Donin offers an epistemological reflection on the way composers' discursive and self-critical skills are embedded in POINT and more generally in artistic research. Self-analysis as a tool for (scientific or artistic) research is both needed and challenging, as recent debates in psychology and phenomenology show.

Sandeep Bhagwati poses the question whether algorithmic composition might one day replace human music making. Starting with our fear of intelligence amplifiers, and delving into the presence and future of listening, he explores the aesthetic impact of computational musicking on our understanding of what music is and what it could be.

Guerino Mazzola analyses part I of Pierre Boulez's *Structures pour deux pianos* and proposes a resynthesis by a computational approach.

David Cope describes how the use of computers in the composing process is a natural outgrowth and continuation of how composers have been using algorithms for composing since the very beginning of recorded time.

Postscript

This project considered a wide range of compositional approaches.[3] Had we limited ourselves to the work of a single or only a few composers, the analyses could, of course, have been brought to a deeper level. However, I placed more importance on the integration of composers from a very diverse range of aesthetic positions and individual practices into the project. Many questions and issues have had to remain unanswered; yet they have opened up space for further intriguing discourse. I hope that the projects presented in this book inspire future work in this direction.

Gerhard Nierhaus, Graz, 29th August 2014

[3] From initially 16 collaborations with different composers we selected 12 which were documented in this book.

Composers' Projects

Elisabeth Harnik/Improvisational Re-assemblies

Elisabeth Harnik, Hanns Holger Rutz and Gerhard Nierhaus

Elisabeth Harnik was born in Graz, Austria, and received her first musical education at the age of five.[1] At the age of 10 she started playing the piano, an instrument that became a constant companion during her musical development. After finishing school she initially studied piano at the Music University of Graz. During her student time she turned at first to jazz and jazz-singing, working with Ward Swingle (Swingle Singers) and continued her education with Ines Reiger, Sheile Jordan, and Jay Clayton in the field of vocal improvisation. Harnik received further important impulses as a pianist by studying the repertoire of contemporary music, participating at the Vienna days of contemporary piano music and she continued to work as an improvisation musician. Harnik did not find until her intrinsic approach of the instrument with free improvisation until meeting the French double bass player Joëlle Léandre, whose musical journey from classical music to improvisation she shared. In the following years she worked as a pianist in various areas of improvisational music and participated, amongst others, in the classes of Peter Kowald, Lauren Newton or David Moss. As a pianist, Harnik looks for the challenge to dissolve or disperse the long-established norms and apparently fixed boundaries of the instrument, where she considers it her task and challenge to permanently re-invent her playing and her instrument.

[1] Biographical introduction and texts from the composer translated from the German by Tamara Friebel.

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However, in her artistic desire to "create" she was looking for an additional means of expression, and this is where her first compositions emerged. An encounter with the Swiss composer Beat Furrer during her participation in Haubenstock-Ramati's *Amerika* conducted by Furrer a few years earlier is still alive in her memory. Harnik received essential further impulses and stimuli for the artistic development from the visits of a "Deep Listening Workshop" with the American composer and accordion player Pauline Oliveros.

After these events, Harnik studied composition at the Music University of Graz with Beat Furrer. Soon after finishing this study, composing quickly became a second essential aspect of Harnik's artistic activities, alongside her practice as a free improvisation pianist. Harnik performed as a piano soloist and in ensembles with prominent representatives of improvisational music at national and international festivals; her composition activities also lead to commissions and performances of her works by well-known soloists and ensembles.

Despite the predominant separation of composed and improvised music in the present performance climate, there are more and more overlaps between both disciplines at festivals for contemporary music or improvised music emerging. In some of her works Harnik relies on a strategy where one influences the other, balancing a connection which uses economical and practical means between improvisation and composition, moving from a confrontation to a synthesis, nevertheless both fields of activities remain in the majority of Harnik's oeuvre rather disjoint. When it comes to composing it is the fascination to move freely along the time-axis as well as the possibility to work meticulously on details of the realisation of sound and form. Improvisation is more about its enforced linear time lapse, but on the other hand she sees it as a "going backward into the future"—with the presentiment of approaching a future which is still open, that has to be shaped artistically as it emerges.

In Harnik's compositional work, she rarely starts at the beginning of a piece; she likes to move erratically along the time line, where structures of a later section often feedback to previous parts. With respect to structures, she likes to work with complex rhythmical and melodic patterns, which are combined and selected in different ways. The musical progressions are notated with utmost precision, which in their frequent complexity open the sought-after "new".

In the compositions of Harnik there is often a refreshing friction and/or tension between self-imposed rules and their modifications, even a breaking of the rules caused by intuitive decisions. The rules open an area of discourse, which gets evaluated and processed by the musical intuition as well as having the effect of completely re-forming the composition.

In her current work, the search for methods to give a composition more flexibility and elasticity, without losing the precision of conventional notation is an important focus of her artistic exploration. In a recent piece, *grafting* (*veredeln*, *aufsetzten*, *anreichern*. . .)[2] she translates methods from other working practices into her composition, for example, the role of how an improvisation orchestra uses signs and hints to initiate their play. These practices widen her scope, leading to modifications

[2] "veredeln, aufsetzten, anreichern" roughly translates to: "refine, setup, accumulate".

and changes within the compositional work. The processes act as a "medium" in order to be able to implement a flexible zone in the conventional musical score writing.

Re-framing II (*inside the frame is what we're leaving out*) for string quartet is composed using an "elastic form". The sequence of the form is set. Within the sections, however, are options for the individual players. The performer can alternate between different types of notational reading. Depending on the selected type of reading, the shape of the time and rhythm-melodic patterns are affected. Through this process, the time frame is reinterpreted multiple times, to bring flexibility within the established structure of the work.

Artistic Approach

Statement

> The nautilus is a nomad which explores the oceans on its vast journeys. It collects particles of each investigated place to build its shell, becoming a sort of collection of its explorations. Every year the shell forms and adds a new chamber. The old chamber is sealed and the animal moves into the new chamber. . .

I see parallels in my artistic work as a composer and improviser to the journey of the nautilus. In both disciplines of composition and improvisation there is a drive for me to obtain something "new" within a particular framework of conditions and thus to extend the boundaries.

As a professional pianist and improviser, my hands have acquired a rich repertoire of gestures. This is further refined, extended or also revised by regular frequent practice and reflexion. It can be described like a ritual: from a state of alert curiosity, in which some decisions are consciously left up in the air, I let myself be guided by the expectation of what will come. I have an attentive anticipation of the possible outcome, but one which can still remain foreign or strange to me. It is like while playing, something can spontaneously occur which is new to the previous context. Hand and ear "localise" the incident and almost "anticipate" the foreign element. I then take this new engagement on with a readiness to take a risk and follow it up. When composing I also choose certain working methods, which make me follow up particular musical incidents spontaneously. Mostly, I do not know which result will come from it, but that is what constitutes the excitement in both disciplines. They are only differing ways to obtain a sought-after "new".

I consider composing and improvising as a kind of interplay between the calculated and the inconceivable: a reflexion about a developed sound vocabulary—be it via preconceived of spontaneous interventions—and a tracing of an unconscious inner structure.

Personal Aesthetics

Whether I write a piece in the conventional sense or I play an improvisation, both are highly complex creative processes. I like to put improvisation and composition as counterparts to each another, and the discussion often ends up being a kind of power struggle or trial of strength where either the one or the other loses. For me however both composition and improvisation represent a complex interplay of activities, which assigns meaning to musical material—I appreciate both disciplines because I can reach something with both different creative methods.

The possibility to move freely along the time-line when writing, to later exchange what's already written with new findings and insight—to let this influence future sections back in the beginning—leads to a completely different approach compared to the linear time structure of an improvisation. On the contrary the challenge of improvisation lies precisely in the brilliance of the moment since no posteriori correction is possible. The role of listening is crucial, which transfers and takes me into a state of subtle presence. Everything that is heard—the carrier of information and relation—is composed or made up of sudden, imminent direct sensory perceptions and sensations, or of a pensive leaning towards old experiences and intuitive presumptions.

In my work as an improviser I meet musicians from all different musical backgrounds. My personal aesthetic is based on a repertoire, which I have collected over many years in my improvisation and composition practice. It is affected by my cultural heritage and education and also by international and intercultural collaborations with performers of various musical genres. Contemporary music, jazz, electronic music, rock music and Indian music have crucially influenced my handling of aesthetic preferences. Improvised music is an artistic area that is influenced by different approaches and positions.

I would call my aesthetic as an improviser "integrative" rather than anything else. It is impossible to deny my central-European heritage—nevertheless I observe, especially in my practice as an improvisation artist, that by the exchange with musicians of other cultures and different genres I am repeatedly encouraged to consider the often unconsciously adopted concepts of western avant-garde art and music. This implicates that I allow a pluralistic point of view in the aesthetic of my improvisation, but of course, there are always boundaries.

Improvisation occurs often as a collaborative act. In my opinion this requires one to be open to "foreign" aesthetics and to be ready to leave behind your own preferences. I would go even further and say that in a group improvisation the group sound, respectively the form of the moment takes primacy over the aesthetic of the individual members. In a group improvisation the various kinds of information processing change. Separated and sequential linear sound vocabulary—with or without a preconceived system—is combined with non-linear, presently sounding, imagined or remembered information.

When composing conventionally or in a solo improvisation, the dimension of the collective nuance is of course missing, which is so eminently important in a group

improvisation. I alone am the "author/originator/creator" of my actions. Nevertheless I often manage also to take on a multi-perspective when composing or playing solos, which allows a plurality of discourses to happen simultaneously, whose individual layers can arbitrarily interrupt each other or respectively pass into fore- or background.

Formalisation and Intuition

Each composition and improvisation carries within a certain interrelation between "interpretation" as formalisation and "spontaneity" as intuition. It is therefore interesting as a composer and improviser to gain within this respective framework something "new".

In recent times, when I compose with pen and paper, I work increasingly with patterns, which I formulate as a form of basic configuration of sounds, which react, to different filter processes. For the filter processes, which blend in and out the sound and motion patterns I use mostly rigid rule-based systems like cellular automata.[3] The almost automatic execution of the rules allows me to react intuitively to the emerging body of sound. Unexpected musical situations often arise for me, which can significantly change the course of a composition, or sound qualities detach themselves from the initially formulated pattern, sound qualities which were not yet determined at the beginning of the composition process. It is an integrative process in which forgetting the rules of a system play an important role since otherwise no change, no transformation is possible. The moment of the sudden "neglect or oblivion" in order to follow up an intuitive idea appears in my work method often as an "insertion", which is incorporated retroactively in the composition—sometimes also retrospectively. Therein, the driving engine is the improvising of solutions, which do justice to the system of rules as well as to the intuition.

The skill of improvising appears however, in the ability to anticipate the sum of all processed information without a comprehensive formal plan or design. Sound after sound, silence after silence is added where the respective form of the moment adapts itself to the actuality. Music itself is considered a field, which is open to all sides, which wants to be worked on artistically. In the flow of an improvisation an overemphasis of intellectual reflexion can detract from the spontaneous action and reaction. Derek Bailey uses the following image: you can approach the unknown with a method or a compass, but with a map you would never get there.[4]

POINT: Our project focuses on your artistic work as a solo improviser, what are the most important components for you in a solo improvisation?

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[3] A cellular automaton consists of a number of cells, which may assume a certain number of states. The temporal development of the system is represented in an n-dimensional cell space, where the cells change their states accordingly to their states and the states of the neighbouring cells.

[4] Translated from the German "Man kann sich dem Unbekannten mit einer Methode und einem Kompass nähern, aber mit einer Landkarte würde man niemals dorthin gelangen".

Harnik: As a composer, when scoring music, I have all the time I would need to finish a composition. As an improviser I create the sound in the moment. In doing so I put myself into a meditative state to follow intuitively an internal structure, whereas the role of a composer and interpreter is merged in the process. The mental and corporal preparation as an improviser/performer for a concert is very important. The performance where creation of music is in "real time" leads to it becoming an event.

The stimulating challenge of a solo improvisation lies in the possibility to deal consciously with one's own personal use of material. Without external intervention I immerse myself in an inner dialogue and am thus able to further explore my performance. Apart from the technical and conceptual exploration of the instrument, solo improvisation is based on the integration of certain elements in real time, with the option of bringing new material into the "game". This spontaneous handling of the material is only possible because the patterns of movement are automated to an extent, freeing up one's concentration to execute and perform new gestures. The particular instrument I play on is also a factor here because instruments can be very different in their build and can "disturb", for instance, the application of "known" material. If an instrument does not react like one expects then this possible irritation holds the potential for a spontaneous finding of solutions.

Moreover, in the course of an improvisation I can react to instantaneous situations in two different kinds of ways, which can be called, according to Lydia Goehr[5] "Improvisation Extempore" and "Improvisation Impromptu". The "Improvisation Extempore" denotes a familiar concept of every day music, namely to make music out of the moment and to develop it. The "Improvisation Impromptu" approaches the example of daily life as originated from a fracture, a problem, where an emergence necessitates an immediate (re)action. We have to react right away, without developing the reaction. In order to create room in a solo improvisation for the "Improvisation Impromptu" I often provoke unforeseen disturbances by risky preparations or materials, which are never fully controllable like mechanical toys, falling objects and similar things.

When improvising I also work very strongly with a knowledge and memory from the body of the instrument. Clusters, chords, and tonal sequences—both in intention and execution—are coupled to basic positions of my hands like "narrow hand", "somewhat open hand" and "far open hand". I also possess a repertoire of movement patterns of the hand along the keyboard, from conventional techniques of playing to self-developed performance techniques.

From my own playing a catalogue of typical basic material can be isolated which is subject to permanent selection and extension: diverse gestures at the keyboard such as melodic micro-segments, chord pattern, cluster forms, rhythmical cells as well as extended techniques, for example the use of mobile and fixed preparation of the interior of the piano, and more common materials from a combination of play on the keyboard and the inside of the piano, glissando effects, percussive play on the instrument body, linear processes of development, sound types, texture types, etc.

[5] Professor of Philosophy at Columbia University, New York.

All this basic material has a common allowance for ambiguity, where changes and adaptations must be possible if necessary. It is also advantageous if these ambiguities can be combined with versatility or if they are not too precisely defined in the area of application. I prefer the use of my bare hands, for instance, when playing in the interior of the piano, compared to using beaters and drumsticks, since quick changes in the sound production are easier done with the hands.

From the viewpoint of an "observer without commentary" I follow the sound formations and refine them, guide them into a certain direction or also reject them in some cases. Altogether one can observe that the sound colour potential of the material and its possible structural development takes primacy over the pitch organisation. Of course the pitch and temporal organisation of the musical events also play a significant role. During an improvisation however, the interval constellations are for me considerably more important than the selection of actual pitches. On the temporal level I work mostly intuitively, with a free combination of aperiodic material and rhythmical micro-segments where an instantaneous forming and sensing plays an important role.

Evaluation and Self-reflection

I do not "think" but at the same time it feels like "knowledge" as my eyes are mostly closed; it is a kind of "no-mind" state. If I think very deliberately about what to play next, I only manage with great difficulty to get into this state of "flow", yet this does not mean that there are no conscious decisions during an improvisation. Conscious moments serve me an "in-between stop" and I don't put too much emphasis on them since I want to be always ready to give up the conscious "control" in the right moment. It seems that I rely on my "bodily memory" and simultaneously move into the role of a "non-commentary" observer, which subtly directs the play.

Project Expectation

As a composer and improviser I am in a permanent dialogue with my own repertoire and the associated possibilities of structuring time. This way of dedicated awareness of the material constantly accompanies my artistic process. From participating in this project I expect a deepening of this debate. First of all I hope to unravel some unconscious processes and the implied knowledge of these processes. Amongst other things I am thus interested in the criteria by which I recognise and ascertain spontaneous discoveries or lucky coincidences, which may open new paths because these form mostly in conjunction with intuitive forces, the basis for artistic decisions. Yet the formation of such criteria can also imply wrong ways and dead ends. These imperfections and mistakes found at the edge between solving and finding problems are important for development.

I think that the analysis of my piano improvisation can also bring out this aspect of "failure", which in return is a possibility to better understand my own methods.

How far it is possible to address the aspect of "embodiment" I cannot estimate. The connection between "hand" and "head" is crucial in my performance practice. As a "composer-performer" I become one with the sound and with the instrument. The basic impulse for every movement are my hands—their size for instance, or the way in which they cooperate, etc. This has a strong influence on my improvisation. This project is, in any case, a new way of reflexion. It contains a new perspective to study and analyse the "pathways of my hands".

Exploring a Compositional Process

POINT: We decided to focus on Harnik's improvisational work for our research. In order to gather some empirical data, we arranged a session in which she would play a number of small "snippets", improvising with a strict constraint such as using only chords of a given number of voices. We recognised Harnik's objection that this situation was highly unusual, however we still considered it useful for some initial observations. Figure 1 shows the relative frequency of frame intervals occurring within the total body of these improvisations. In contrast and reflecting the internal interval structure, Fig. 2 shows histograms of the neighbouring intervals occurring within chords of given sizes.

With respect to the frame intervals, the major seventh is particularly prominent, whereas minor seventh and major sixth are seldom. There are only few instances where octaves occur. With respect to the layered intervals the fourth and the tritone are prominent, except for the series of chords of four voices, where the major third is very frequent.

Harnik: It is of course clear that within my normal improvisation process, such sequences of constrained chords are unlikely to occur. Harmonic consonances arise, though, due to diverse conditions, such as the physicality of my hands, movement patterns that have developed in the course of my improvisational activity, and also arise due to the transformation of melodic phrases. Nevertheless, these analyses show very clearly my harmonic preferences and motivate me to consciously break the patterns.

Would it also be possible to create new musical structures from my improvised material? I have indeed seen some interesting approaches to regenerating Bach preludes from existing preludes during our meetings. Such an approach would also be exciting for me, as it might be able to produce something like a mirror of my improvisational preferences.

POINT: There are various possibilities to generate musical structures using a corpus of existing data, such as using context based methods operating on prefix- or suffix-trees. A particularly interesting method is the *context snake* [3, pp. 112–117], an algorithm that moves along a context tree, effectively providing variable length Markov chains. The next section will introduce this concept and the possible configurations.

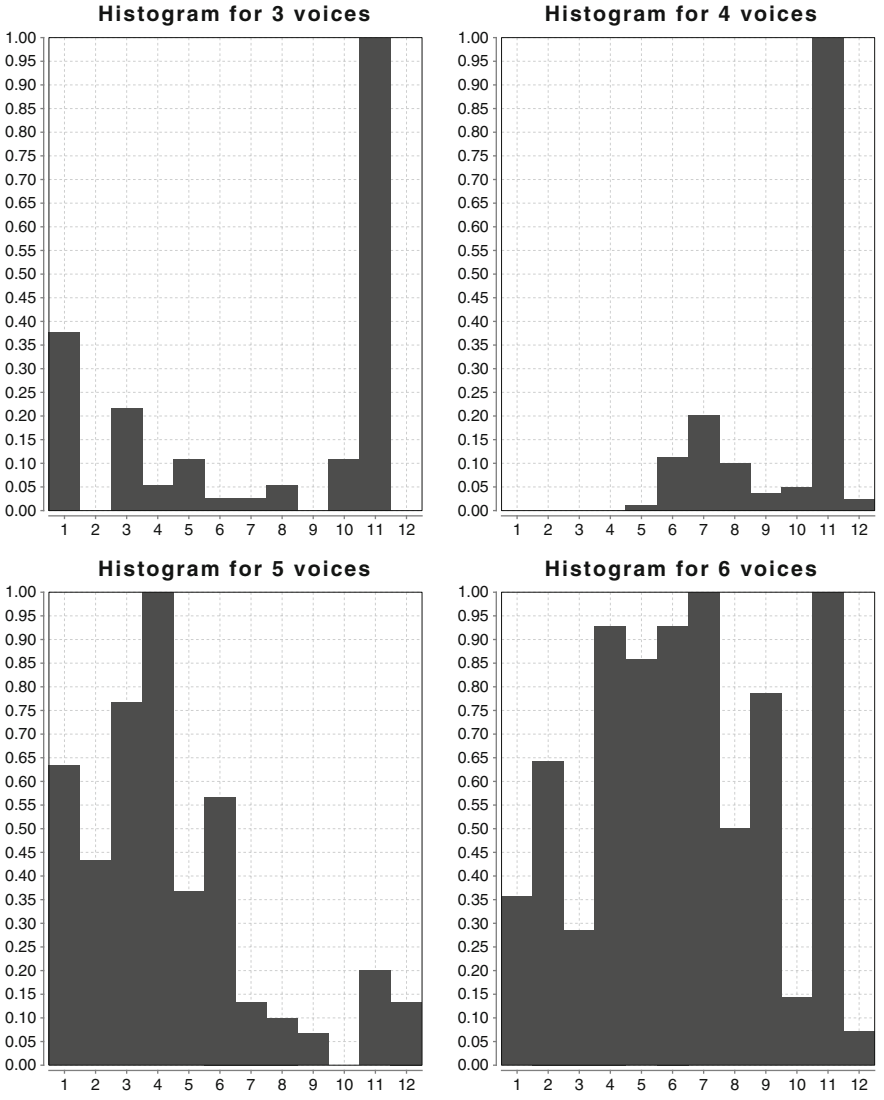

Fig. 1 Frame intervals in the chord-only improvisations, for a given number of voices. Intervals greater than an octave are wrapped

Since we have access to the data produced by Harnik's play and more data can be produced on demand, we decided to train a computer algorithm so that it could somehow reproduce the improvisations, thereby revealing certain aspects that are modelled convincingly, and others that are not well captured. This would engage Harnik in a dialogue and help to explicate the aspects of the play that are only intuitively and implicitly known.

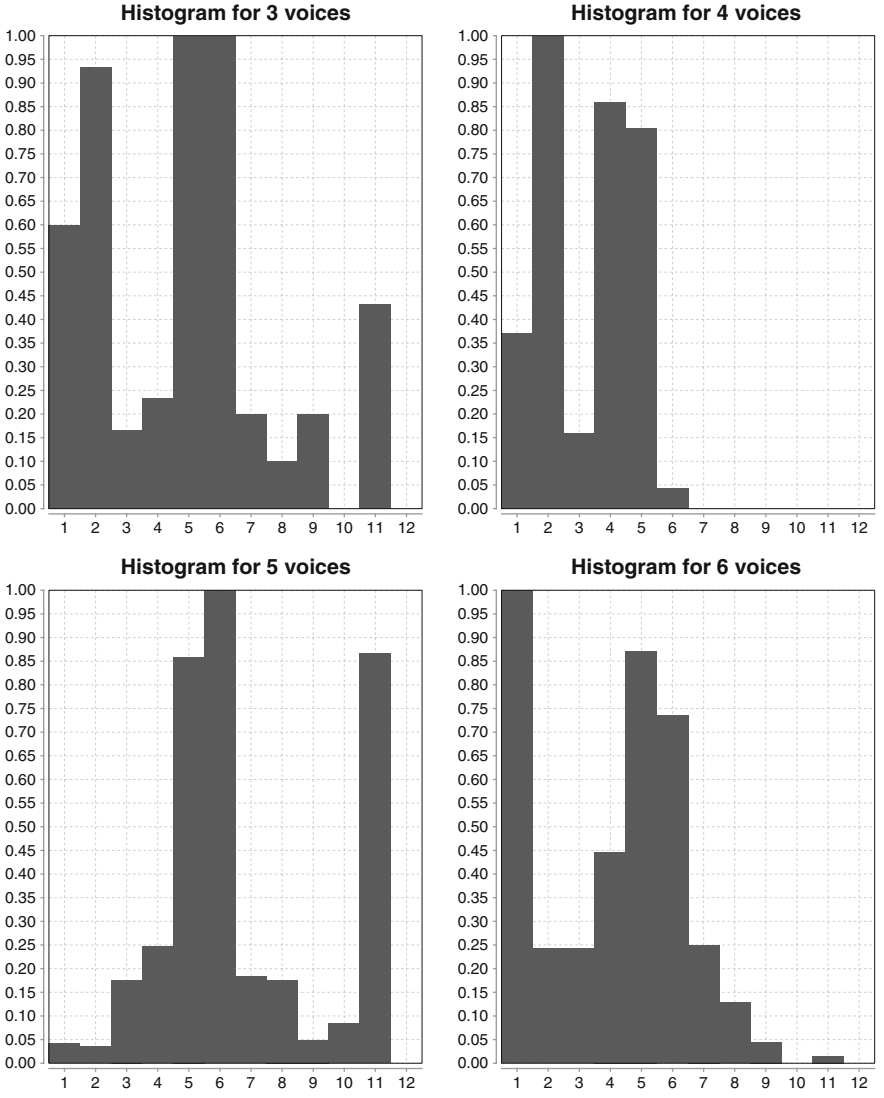

Fig. 2 Layered intervals in the chord-only improvisations, for a given number of voices

A classical approach of modelling a sequence of events—such as pitches played on the piano or letters forming words of text—is to create a table of probabilities that describe the chances of getting from a particular event or state to another event or state. The table of probabilities may be the result of analysing an actual body of events (the corpus). Using chance operations, new chains can then be formed which resemble the original corpus with respect to the statistical properties of event frequency and transition frequency. These chains are called Markov chains, because

Table 1 First-order Markov transition table for intervals in a free improvisation

	0	1	2	3	4	5	6	7	8	9	10	11
0	0.05	**0.22**	0.17	0.08	0.03	0.06	0.07	0.04	0.04	0.05	0.05	0.13
1	0.05	0.13	**0.17**	0.05	0.08	0.06	0.10	0.11	0.07	0.07	0.05	0.06
2	0.05	0.13	**0.13**	0.07	0.08	0.11	0.09	0.08	0.09	0.06	0.04	0.04
3	0.02	0.11	**0.20**	0.08	0.08	0.08	0.03	0.08	0.08	0.04	0.06	0.14
4	0.04	0.10	**0.21**	0.07	0.09	0.06	0.10	0.10	0.04	0.07	0.06	0.05
5	0.07	0.12	0.12	0.06	0.06	0.11	0.10	0.08	0.05	0.06	0.04	**0.14**
6	0.05	0.15	**0.16**	0.05	0.07	0.10	0.05	0.10	0.06	0.08	0.05	0.09
7	0.04	**0.14**	0.13	0.10	0.10	0.07	0.08	0.09	0.08	0.03	0.05	0.10
8	0.02	**0.16**	0.12	0.13	0.07	0.05	0.12	0.11	0.04	0.09	0.02	0.07
9	0.04	0.11	0.13	0.08	0.06	0.06	0.09	0.08	0.06	0.05	0.09	**0.17**
10	0.06	0.11	**0.14**	0.08	0.09	0.10	0.07	0.06	0.04	0.09	0.04	0.12
11	0.04	0.13	0.10	0.09	**0.14**	0.06	0.04	0.07	0.10	0.07	0.06	0.09

Each cell shows the probability of a transition from the row index to the column index. The sum of each row is 100 %. The largest probability of each row is shown in bold-face

they have been invented by Russian mathematician Andrey Andreyevich Markov at the beginning of the 20th century.[6]

As an example, Table 1 shows a transition matrix created from looking at the succession of intervals in the recording of one of Harnik's improvisations. The intervals are shown as the number of semitones modulus octaves. Looking at the first row, the probability that a pitch repetition (unison) is followed by another pitch repetition is 5 %, whereas the likelihood that a unison is followed by a minor second is 22 %. Using this table and a random number generator, one could now generate new sequences of pitches that reflect these probabilities.

The problem with this approach is that the generative process is not sensitive to rules or probabilities that involve a longer back trace than just the preceding element. For instance, the corpus might contain transitions $A \rightarrow B$ and $B \rightarrow C$, but no subsequence $A \rightarrow B \rightarrow C$ exists. A first-order Markov process that only looks at the last element to produce the successor may come up with this result. One can use higher-order Markov chains to avoid this problem. In a second-order process, transition probabilities are given for pairs of preceding elements. On the other hand, the higher the order, i.e. the more the transition rules are constrained by looking at the longer backtrace of the sequence, the less likely one finds alternative transitions. The effect is that the original corpus will be more or less recreated without variation. At the same time, patterns that clearly reflect low-order Markov processes are concealed in such higher order representations.

To navigate between these two extremes—context-insensitivity at low orders and lack of variability at high orders—Kohonen has proposed the use of variable-length Markov chains [2]. His generative algorithm tries to use long contexts (high orders)

[6] For an overview of Markov chains, see for example [1, Chap. 11] and [3, Chap. 3].

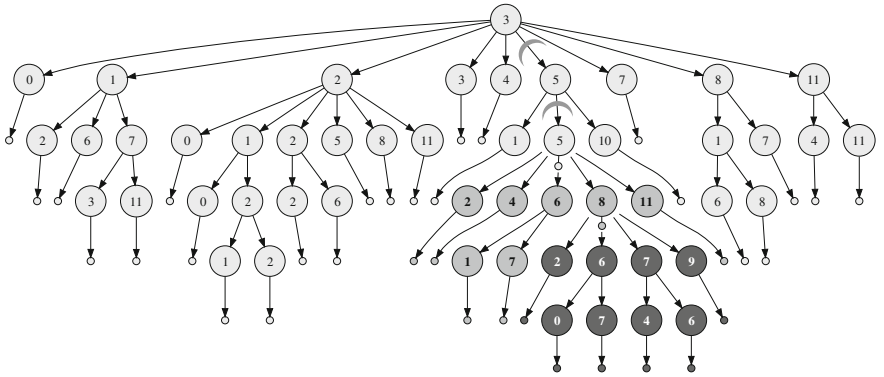

Fig. 3 Snake motion through a context trees of intervals. The initial tree, starting with element 3 and shown in *light gray*, successively expanded trees in medium and *dark gray*

but is restricted by a *depth parameter*, ensuring that the exploration stops before the maximum context length is reached, thus guaranteeing a choice in the successive elements of the generated sequence. A particular rendering of a variable-length Markov algorithm is the context snake. It builds a tree structure of the overall context. The "body" of the snake is the current context, a subsequence within the corpus. The tree structure allows us to find the successive elements of the current context. When there is zero or only one possible successor, the algorithm may either backtrack and move the snake's "head" towards other sub-trees, or it may truncate the context, forgetting older elements and shrinking the snake's "tail". Efficient search structures are available for the implementation such as suffix trees [5].

Figure 3 shows a traversal through such a suffix tree. The data used is a subset of the interval transitions used for Table 1.[7] The snake was initialised with only one element, 3. At this shallowest context depth, there are nine possible transitions: 0, 1, 2, 3, 4, 5, 7, 8, 11 (for simplicity, the edges are all drawn the same, although the transition probabilities differ). If, using a random number generator, 5 was selected as the successive element and appended to the snake's body, the context depth becomes 2, and now there are three alternative successors: 1, 5, 10. If 5 was selected again, the context depth or snake length becomes 3, but now the critical point has been reached where only one possible successor (6) exists. The algorithm could backtrack and try 1 or 10 instead of 5. Since these also do not provide longer context, the tail element 3 is removed and appended to the generated sequence. A new context tree starting with 5, 5 is found and the new set of successor elements becomes 2, 4, 6, 8, 11. The procedure is repeated as before, until the desired length of the generated output is reached.

Two aspects determine the quality of the generated sequences. Firstly, the size and exhaustiveness of the corpus—the larger the corpus, the more it reflects the knowledge embodied in Harnik's play, the more exhaustively it covers all the possible

[7] We used a smaller corpus to make the figure more readable.

ways of conceiving such improvisations. The second aspect is the type of element represented by the context trees. In the previous examples, we have used the intervals between successive notes. It did not make a difference between an upward and a downward interval, so one would probably want to preserve the interval direction. Instead of intervals, one could use the absolute pitches, or one could model entirely different parameters such as the dynamics of the notes, their durations, etc. A particular problem is posed by the request to model multiple parameters at once, such as pitch and duration. This will be discussed later in the chapter.

To begin with, we tried to regenerate plain chord sequences, using a given number of voices. Examples of the input material are shown in Fig. 4. To model the generation of new chord sequences, an example corpus was first converted from raw MIDI notes to chord objects. In order to keep the dimensionality of the vectors small and the amount of alternatives high, we used multiple context snakes whose outcomes were combined: the first snake generated was fed by vectors formed from the pitch class taken from the lowest and highest note of each chord. For example, looking again at Fig. 4, the first chord would produce frame pitch classes (G, G) or numerically (7, 7), the second chord would produce (Ab, C) or (8, 0). A second snake used tuples of the registers (octaves) in which the lowest and highest pitches of each chord occur. Using MIDI conventions, the first two chords of the previous example would yield tuples (3, 5) and (2, 5). If chords of mixed size should be modelled, another snake would just generate the chord sizes.

To model the interval structure between the frame intervals, we maintained a nested dictionary from frame interval size to chord size to chord intervals. After determining the lowest and highest pitch of a generated chord, using the pitch class and octave snakes, we looked into this dictionary for the thus given frame interval and chord size. If no entry was found, we looked at the next smaller or greater interval and chord sizes, until a body of chords was found. A random chord is then picked, and its intervals are used in a random layering. Example generations are shown in Fig. 5.

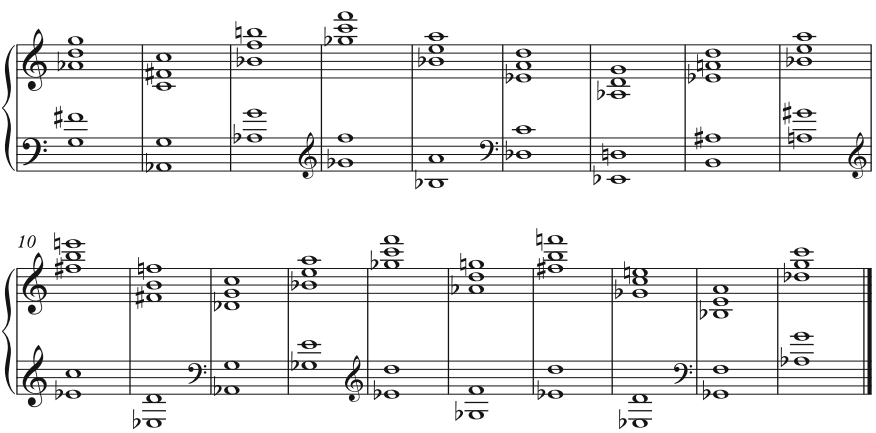

Fig. 4 Example chord sequence played by Harnik (cutout from recording No. 46)

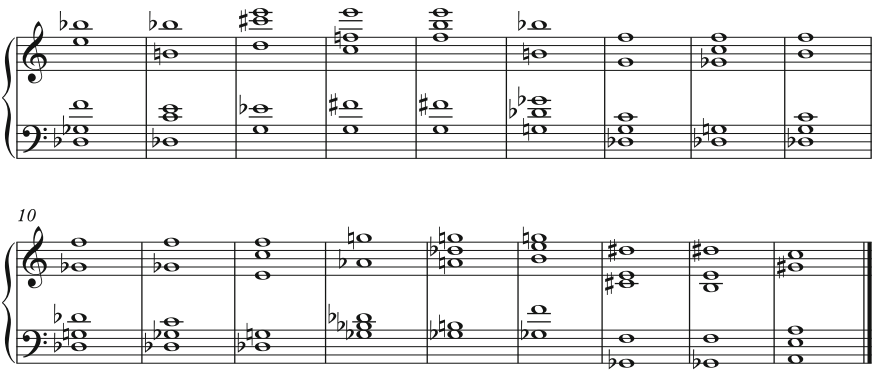

Fig. 5 Regeneration from recording No. 46

POINT: What do you think about the chords from our regeneration?

Harnik: Apart from the chords that are not possible to play due to their position for the hands, the regenerations are convincing. The consciously preferred interval combinations are reflected in the regenerations very well. The chords in bars 10 and 11 I would rather have played as 6-part chords. The combination of fourth and tritone, respectively, in the chord of bar 13 is also a very unlikely scenario.

I would also have formed the sequence of chords differently. Chords in a row are usually intuitively grouped during playing. Pedal points both in treble and bass would not normally be part of my repertoire. It would be more likely to have a single pedal point either in the treble or in the bass, but in this case I would have placed the flow of these chords only under certain conditions, deliberately and with effects that would follow.

POINT: In the next step, we regenerated freely improvised material. In order to handle the articulation of horizontal sequences, the entry delays—the time that elapses between two successive notes—needed to be modelled, and also the dynamic contour was a desirable property to be accounted for. Both velocity values and temporal values are problematic because they are theoretically continuous and practically represented using fine grained digital resolution, such that in a MIDI recording. So only with very low probability we would find identical velocity or duration values.

To produce meaningful corpora, we reduced the resolution of velocity and temporal values using a coarseness parameter. The velocity is linearly quantised from its original MIDI resolution of 127 to, for example, $127/6 = 21$ steps. For the entry delay, we used logarithmic quantisation based on a coarseness parameter that specifies the number of steps per "time octave". For example, with a coarseness parameter of 2, time values would be quantised to the nearest of 10, 14, 20, 28, 40, 56, 80 ms, etc.

Again, in order to keep the tree branching factors in the corpus high, we used separate snakes to model the pitches and to model the entry delays. With the entry

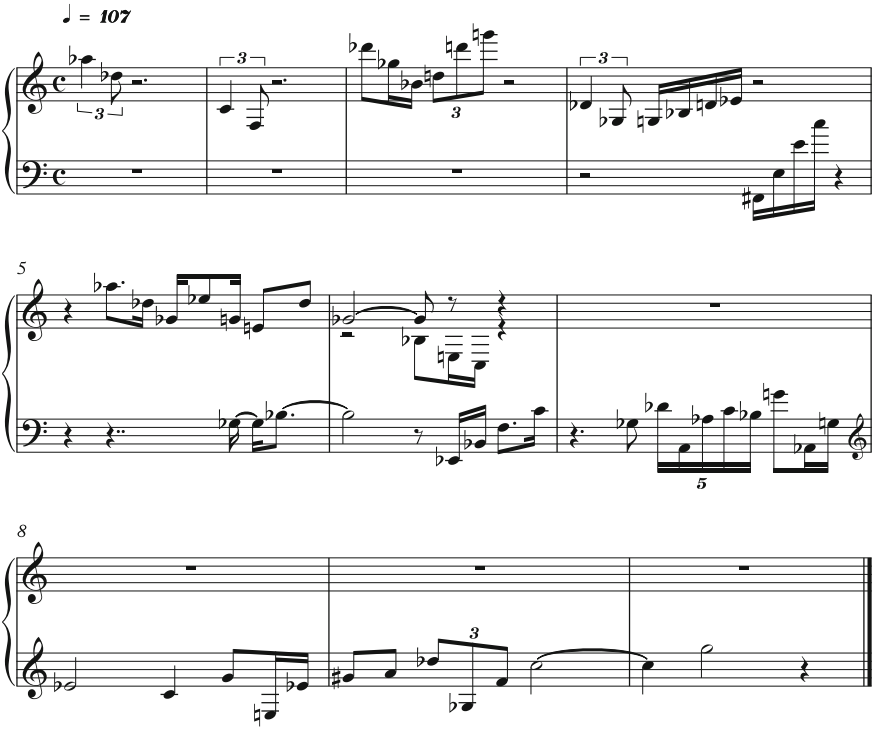

Fig. 6 Cutout from recording No. 48

delays being formed both from melodic progressions and chords, chord structures automatically appeared depending on the entry delays (if a chord appeared in the corpus, the entry delays for all but one note were nearly zero).

Besides making a selection from recordings of Harnik's free improvisations, the initial note and the seed of the pseudo-random number generator—used when a tree has multiple branches—influenced the development of the generated material. Figure 6 shows an excerpt from a recording of Harnik's play, and in contrast Fig. 7 shows material regenerated using the context snake method.

POINT: What do you think about the regeneration from recording No. 48?

Harnik: The interval structure and also the rhythmic flow of the regeneration are convincing. It is striking however, that in my recording the interval of the initially played fifth is then reflected back in further bars of the piece. The interval "floats" permanently as a thought, without manifesting itself. This aspect is only captured in the beginning of the regeneration.

POINT: Figure 8 shows a different excerpt from a recording (No. 9) of Harnik's play. We ran another regeneration, combining this recording with the previously shown one (No. 48). An example from the regeneration is depicted in Fig. 9. In contrast to the previous example, we used a separate modelling of horizontal and

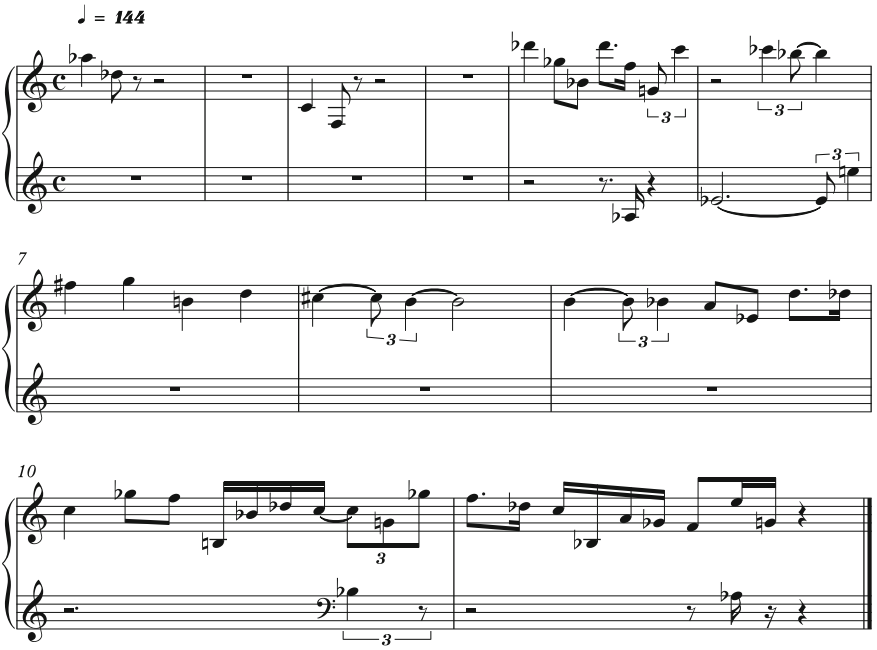

Fig. 7 Cutout from regeneration of recording No. 48

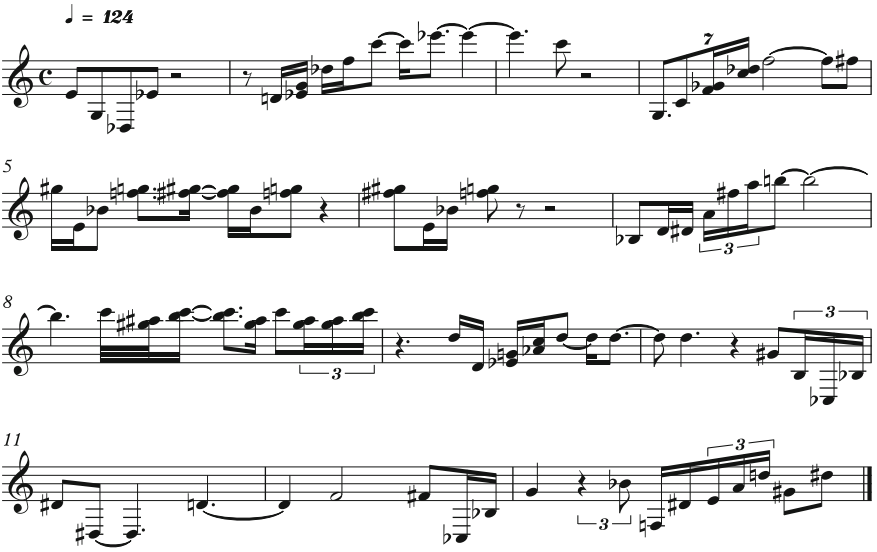

Fig. 8 Cutout from recording No. 9