The Musical Interactivity Area - An Attempt to Map the Intersection Between Composition and Instrument Through the Use of the Gestrument Engine

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***Abstract*—This paper describes the use of the Gestrument Engine as a tool to develop a more articulated understanding of the interaction between user and digital instruments in musical creativity. Through the use of the Gestrument Engine, the paper seeks to develop a new model, the Musical Interactivity Area. This is a visualisation of the area between a composed piece of music and a playable instrument, mapping out possibilities that arise when using tools where it is possible to both pre-define the confines of the input data as well as the structural and temporal musical content. The Gestrument Engine is used by defining several alternative versions of the same musical rules, and later positioning these versions within the Musical Interactivity Area to exemplify the model.**

I. Introduction

With Digital Musical Instruments (DMIs) and musical software in general, it is possible to set the confines of the musical input in ways that make the division between a playable instrument and a composition somewhat ambiguous. Aspects of this have been discussed by R. Rowe [1], S Jordà [2], M.A.J. Baalman [3] and P.A Nilsson [4], among others. Previous research trying to formalize and categorize DMIs or musical instruments in general have often focused on either the performance behaviour/performance context, like J. Malloch, D. Birnbaum, E. Sinyor, M.M. Wanderley [5], or talked about the different aspects of musical affordances, as introduced in music research by E.F. Clarke [6], and further developed across the past decades by authors like L.W. Windsor and C. de Bézenac [7]. When discussing Human-Computer Interaction (HCI) in Digital Musical Systems, T. Magnusson [8] examines the three concepts of affordances, constraints and mapping in ways that touch on the question raised here regarding the somewhat uncharted area between instrument and composition in DMIs.

Further, the notion of Internet of Musical Things (IoMuT), as discussed by L. Turchet, C. Fischione, G. Essl, D. Keller, M. Barthet [9] and the concept of Smart Musical Instruments (SMIs) as examined and defined by L. Turchet, A. McPherson, C. Fischione [10] and L. Turchet [11], visualizes the possibilities of new forms of interaction with both physical and digital agents where the lines are blurred between an instrument and a composition, as well as between who is considered to be artist and audience. When it comes to the definition of what constitutes an SMI, one aspect mentioned is embedded computational intelligence, which can be present in many different ways. One way this could be included is through the use of predefined musical rules of constraints, like those discussed in this paper.

This paper addresses perspectives that are closely related to the development of SMIs, as well as those of non linear music that can be found in for instance video games, and will therefore look at these questions from the angle of what constitutes an interactive composition. The method adopted in this paper is designed to test a tentative model, the aim of which is to map a field of different affordances and constraints in a DMI. Specifically, the proposed model of the *Musical Interactivity Area* aims to conceptualize the possibilities that come with malleable musical confines built into instruments. Confines are of course always present in any instrument, but when these rules can be gradually or suddenly changed, the instrument itself can be morphed and reconstructed while a user explores its affordances. Hence, the affordance structure of the instrument is malleable through the instrument design. Hereby, the actual instrument becomes more of a composition in itself. The model aims to be a tool for examining, and hopefully also creating, new ways of musical interaction for composers, performers and audience alike.

II. An overview of The Gestrument Engine

A. A brief history

In 2007, the first version of Gestrument (not named Gestrument at the time) was developed by Jesper Nordin using a Wacom tablet and a Max/MSP patch. It was used in its original form in many compositions, for instance *Surface scintillantes* (2007, for ensemble), *Vicinities* (2011, for bassoon and orchestra) and *Pendants* (2009, for ensemble and live electronics). In 2012 it was released as an iOS app called Gestrument, developed and designed by Jonatan Liljedahl in close collaboration with Jesper Nordin. In 2018 a new app called Gestrument Pro was released, again developed by Jonatan Liljedahl and Jesper Nordin. In this version, the technical concept (see more below) was made more generic and modular to be able to open up for further development in several different directions, both in regards to use cases and musical styles and genres. The iOS apps have been developed directly in XCode, making use of the built in tools of iOS like AUSampler and IAA (Inter-App-Audio). They are Universal apps, so they work on both iPad and iPhone, even if the larger screen of an iPad makes for a more expressive tool.

After the development of these apps, the focus has been to port the more generic version of the technology in Gestrument Pro to a C library called the Gestrument Engine, so that it can be ported to any platform and many new potential use cases. This has mainly been done by David Granström and Peter Gebauer, with the assistance of Jonatan Liljedahl, Jonas Kjellberg, Pär Gunnars Risberg and Jesper Nordin. For in-depth description of the technology itself in its current state, the online user guide and the video tutorials on the website of Gestrument [12] are better suited than trying to summarize the technology in this paper .

B. Technical concept

The first basic concept was a mapping of pitch and rhythm on an X/Y area. At first, pitch was a list of numbers and rhythm was subdivisions of the tempo. One major aspect that made the concept different from many other X/Y instruments was the way it integrated pulse and rhythmic patterns, allowing for the possibility to play in sync and with specific rhythmic patterns, but still being able to play long notes without said pattern. This in combination with the possibility of playing multiple instruments at once made for a very powerful compositional tool in itself. Early on, support for micro intervals and morphing between scales was added, as well as the possibility to import MIDI-files and use those as scales, which made the morphing feature even more versatile.

The development of Gestrument Pro started with the idea to take the concept of the original app and develop a generic version of it. The model used was that of a "Pitch Generator" and a "Pulse Generator" that can be combined to produce musical events in real time - either on its own, or driven by user input of some sort. The user input was based on the X/Y input of an iOS app, but it was not confined to that concept since other use cases have include the Gestrument Engine being driven by motion sensors or in-game actions in video games.

The generators were at first modeled on the original app with lists of pitches and note values, but more have since been added and planned, spanning from simple pattern generators, via different MIDI-file readers to algorithmic generators.

C. Current state

Apart from the app Gestrument Pro, the current state of the technology is defined as how it is implemented and developed in the Gestrument Engine. But for this paper it is the iOS app Gestrument Pro that is used to map out the Musical Interactivity Area. The current state of the development of the Gestrument Engine is driven by an ongoing search for new ways of both exploring and redefining what musical interaction can be and how it can be used in different contexts, and therefore this proposed model will be used internally as a tool for both core development and for driving the development of different types of applications based on the Gestrument Engine.

III. The Musical Interactivity Area

A. Towards a model for musical interactivity

The Musical Interactivity Area aims to be a model to describe situations where the identity of a DMI is situated between a composed piece of music and a playable instrument. It will not be an attempt at describing, or to fully explain the interaction models and possibilities in DMIs or SMIs in general. Rather, the focus of this paper is on the field that appears when you can pre-set both confines to the input data and predefine the musical structure within the same context, no matter what that context is. There are several dimensions in such an area that could be of interest when researching these questions (see for instance D. Birnbaum, R. Fiebrink, J. Malloch, M. M. Wanderley [13] for discussions on the use of multiple dimensions when discussing musical instruments). However, for the purposes of this paper, the focus will be on two axes, outlined in the following section.

It might seem counterintuitive to name a model Musical Interactivity Area and define the axes through the amount of constraints and predefined structures. The reasoning behind this is that the model is not looking to establish the situation with the most freedom for the interactive participant, but is rather trying to find the area where there is a balance between control and freedom, and in future research use this as the framework for discussing new ways of experiencing and creating music.

B. Definition of the two axes

The two axes employed in this paper are "Predefined musical structure" and "Predefined constraints in the performance tool/instrument". The Y-axis stretches from "Random sounds" to "A specific performance of a defined composition in a specific genre/style". This axis is relatively self-explanatory and since it is a continuum there is no need to exactly define where any given musical situation would fit onto that axis. It is important to point out that the predefined musical structure can be implied rather than explicitly stated, for instance in the case of improvising musicians from genres/styles that share, or are aware of each other's, style while improvising.

The X-axis can be seen as related to the theory of affordances [6]. The affordance structure of a DMI entails that there is an immediate interrelation, or even overlap, between the two axes, and hereby some choices might be made in either of the axes. For instance, if you define a rhythmical pattern it could either be part of the predefined musical structure—as a characteristic of a composition or genre/style—or it could be a constraint within the performance tool/instrument, that only allows you to perform said rhythmical pattern. It has to be stated that this interconnection between the axes also implies that it is not possible to perform all conceivable music with any given tool/instrument. This is obvious, since aspects of the predefined musical structure might be unobtainable with a certain constraint in the performance tool/instrument. However, this is not something that is specific for DMIs, since the affordance structure of any physical instruments will invoke similar limitations as to what music can be performed.

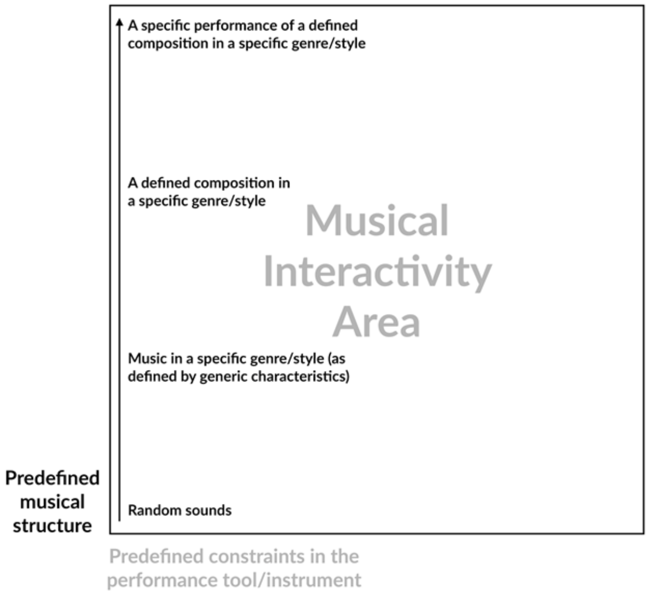

Fig. 1. The Y-axis is a continuum from "Random sounds", via "Music in a specific genre/style (as defined by generic characteristics)" and "A defined composition in a specific genre/style" to "A specific performance of a defined composition in a specific genre/style".

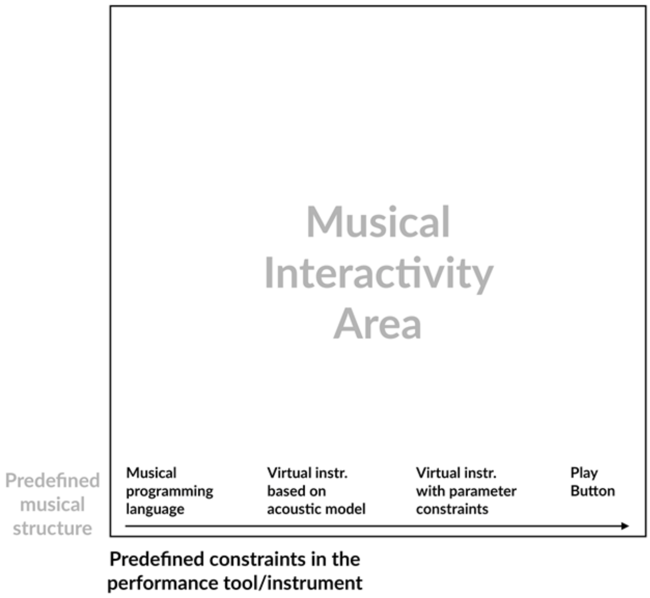

Fig. 2. The X-axis is a continuum from "Musical programming language" via "Virtual instruments based on acoustic models" and "Virtual instruments with parameter constraints" to "Play button".

C. Implications of the different areas

Without any claim to absolute precision, it is still possible to map out some implications of the different areas of this model, as seen in Fig. 3. These implications cover most common use cases of music and music making; the mastery needed when performing a specific composition on a traditional instrument; the limited possibilities for personal expression when setting strict constraints in a performance tool/instrument; or the limited reproducibility when the predefined musical structure is very low.

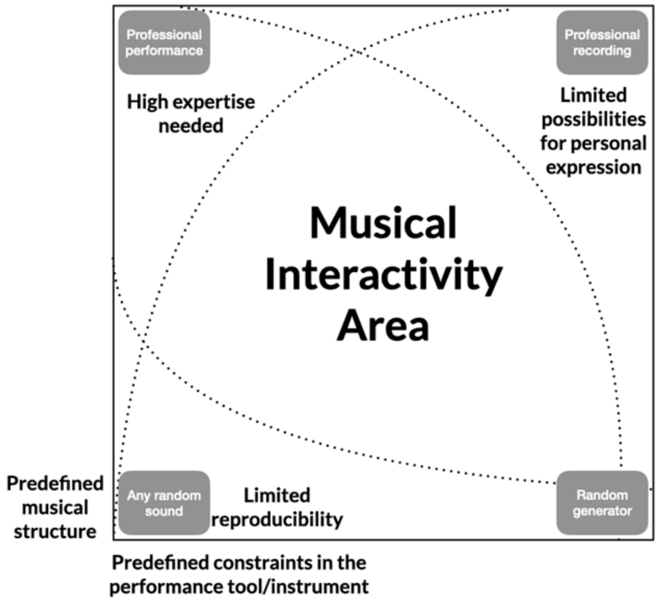

Fig. 3. Implications of different parts of the area are noted directly on the background; "High expertise needed", "Limited possibilities for personal expression" and "Limited reproducibility". The badges at the four corners are reference points/extreme cases of the model: "Professional performance", "Professional recording", "Any random sound" and "Random generator".

To give some reference points, it is possible to explain the four extreme cases covered in this model (also in Fig. 3). The lower left corner is probably the most problematic, since it describes a peripheral location, which is more of a hypothetical rather than actual possible performance situation. The top two corners represent the vast majority of common everyday musical situations, with performances by professional musicians situated to the left and recorded music to the right. These four extreme cases will all share traits with two other extreme cases: "Any random sound" and "Random generator" both share having little to no predefined musical structure; "Professional performance" and "Professional recording" both have a fully predefined musical structure; "Any random sound" and "Professional performance" both share the openness of little to no predefined constraints in the performance tool; finally the "Random generator" and the "Professional recording" both share the maximum predefined constraints in the performance tool - namely both being activated by an on/off button.

D. Mapping the Musical Interactivity Area

This paper is a first attempt at exploring the model of the Musical Interactivity Area and it is done through the use of the Gestrument Engine. The reasoning behind this is that the idea behind the model originated from this technology and therefore it is used as a first test to map and validate the model. By using only one single musical reference, and changing its parameters slightly, it is possible to exemplify different positions within the Musical Interactivity Area. The aim is to make small differences that are still clearly noticeable in comparison, since some parameters stay the same. One challenge with mapping out a model while it is being constructed, is that it is difficult to decide on the methods to use. Since the idea for the model came before these examples, there is a risk of confusing the methods and the results. That being said, there are still many possibilities in researching the model and the methods in parallel, even though the process might become longer. Instead of defining a generic model for the methods used, they are chosen from the most obvious parameters that clearly affects one of the defined axes, and which can be changed easily in Gestrument Pro. In most cases it is rather intuitive to place parameter mappings to one axis in the model.

On a technical note, it is important to point out that any change of a musical setting in the Gestrument Engine will by definition be a change made on the X-axis of the model. But from a conceptual point of view, and for the purpose of defining the model, it becomes natural to place for instance the amount of randomization or the pre-recording of a chord sequence on the Y-axis.

IV. Five Different Versions of a Klezmer Preset

A. Original recording

The Klezmer song used as a base for the different settings of the Gestrument Engine in this paper is a recording of *Klezmer Dance No. 2* by Göran Fröst, recorded by Martin Fröst and the Royal Stockholm Philharmonic on the album *Roots* released by Sony Classical in 2015. More specifically it is the section from 01.22 - 02.12 with the strings playing pizzicato. The recording can be found on Spotify [14] or Apple Music [15].

B. Performing on Gestrument with Martin Fröst

Before starting this study, the setting was validated together with Martin Fröst who performed a version of this music with Jesper Nordin. This was done to validate the quality of the musical output, and to be able to optimize the settings in Gestrument Pro to ensure that the core of the composition was well represented. It is possible to see the performance in a video on YouTube [16].

C. Five different settings

The "Klezmer ver. 1" is the one used in the performance with Martin Fröst, mentioned above. It was designed to provide possibilities to interact with the music in ways that were clearly perceivable for the performers. Based on this case, the other four versions were designed to exemplify different positions in the Musical Interactivity Area. The "Klezmer ver. 2" was designed with a less predefined musical structure and less predefined constraints in the performance tool, while version 3 was designed with more predefined musical structure and predefined constraints. Hence, they both combine a higher or lower predefined musical structure with having similarly higher or lower predefined constraints in the performance tool/instrument. Versions 4 and 5 explore positions in the Musical Interactivity Area wherein the agency of a particular axis is highlighted. I will further outline the differences between the five versions below.

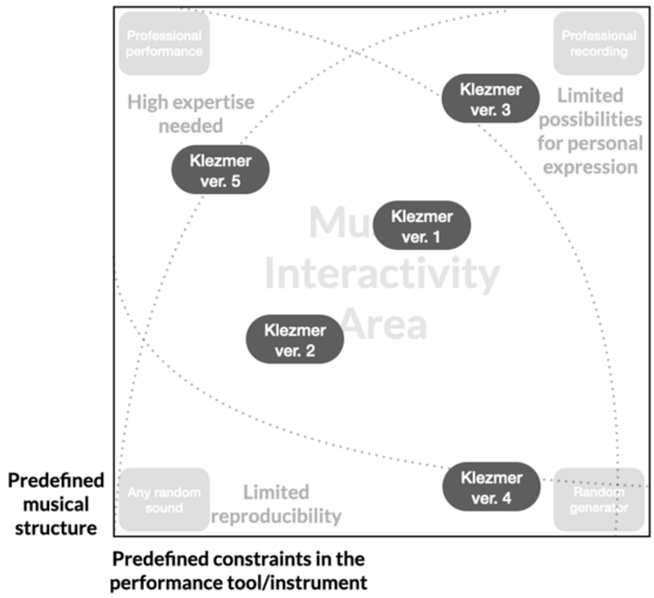

Fig. 4. The mapping of the five different versions of the Klezmer settings.

D. The settings in "Klezmer ver. 1"

When trying to create an interactive version of a specific song in the Gestrument Engine, there are many parameters to define. Without going into all the details, the possibilities of the Gestrument Engine allows for defining rhythmical aspects like patterns and/or different note values as well as aspects related to pitch like range and scale/pitch material. All this is done per instrument, which is defined as a single music event producer. The instruments might be grouped together and controlled by a single input, or mapped to be controlled by several inputs.

Since "Klezmer ver. 1" was the starting point, it was important to define fundamental parameters that could stay the same in all variations, and then choose a few parameters to highlight the difference in position within the Musical Interactivity Area. The parameters that were defined in the "Klezmer ver. 1" and then kept the same for all the other version were the following:

1) General

- There are seven instruments but they are all controlling similar sounds (in the video examples they are all sent to individual Dulcimer sounds in Logic Pro).
- All instruments are mapped to a single control input (called a cursor in the Gestrument Pro app).
- Tempo is set to BPM 86, but with the possibility to gradually change it between BPM 86-98.

2) Rhythm

- Note values vary between half notes and 32th notes with no tuplets and no dotted note values (apart from one of the bass instruments that uses dotted 8th notes).
- All instruments have an individual range of accessible note values.

- Rhythms go from longer note values and less activity on the left side of the X-axis to shorter note values and more activity on the right side of the X-axis.

3) Pitch

- The range of each instrument is different, both in exact numbers and in how many pitches it encompasses.
- The specific pitches are given by the global scale slots, so the only available pitches at any given moment are the ones that are part of the chord that is currently chosen in the scale slot.
- The chords set in the global scale slots are the chords used in this segment of the piece; D-minor, A-major, D-major and G-minor.

E. The settings in the other versions

When trying to identify parameters that affect the settings in a way that is clearly shifting its position in the Musical Interactivity Area, the focus needed to be parameters that were as clearly situated in one of the two axes as possible. The four parameters that were chosen are; “Automated chord sequenze”, “Randomizations”, “Predefined rhythmical patterns” and “Automated cursor/slider control”, as highlighted in Fig. 5. There are many more possible combinations of these four settings, and in future research it might be of interest to look into more different combinations of these, or other, parameters.

Klezmer versions in Gestrument Pro

	Klezmer 1	Klezmer 2	Klezmer 3	Klezmer 4	Klezmer 5
Automated chord sequenze (Y)	Yes	No	Yes	No	Yes
Randomizations (Y)	Some	Some	No	Yes	Some
Predefined rhythmic patterns (X)	Yes	No	Yes	Yes	No
Automated cursor/ slider control (X)	No	No	Yes	Yes	No

Fig. 5. The parameters used to differentiate the five different versions of the Klezmer preset.

Another important aspect to the chosen parameters are that they were all simplified for use in this paper. The unused potential for a higher level of detail in the Gestrument Engine might be a future tool to articulate the Musical Interactivity Area even further. To more clearly understand the parameters used they will be described in more detail here:

1) Automated chord sequenze

- Even though the scale slots are set up using the same four chords in all presets, they will only be recorded as a chord sequence (defined in time) for the presets that have a *Yes* in this column. In the other presets they will need to be changed manually. Technically this chord sequence is done as a loop recording of the changing of scale slots.

2) Randomizations

- There are many ways to use randomizations in Gestrument Pro, so this parameter has three degrees; *Yes*, *No* and *Some*. In this instance, only the *No* is clear, since it refers to a situation without any randomization. *Yes* means that there is always some degree of randomization, and *Some* means that there are randomizations in certain areas of the playing surface. The randomization only affects the pitch material, and they are always kept within the current scale/pitch material.

3) Predefined rhythmic patterns

- The use of rhythmic patterns in these settings are confined to only three of the seven instruments, the others always use a list of defined note values. So even though it would be possible to have a large number of different degrees of predefined rhythmical patterns, in this context it entails a binary option of *Yes* or *No* for these three instruments.

4) Automated cursor/slider control

- The use of automated cursors and sliders have almost limitless possibilities. However, in this case, as with the predefined rhythmic patterns, it is used in a binary way. One loop was recorded, and this recording was only used in the versions where *Yes* is indicated in this row. The length of the loop is equal to the entire section of the song (the same length as the automated chord sequence).

F. The settings in Klezmer ver. 2-5

The changes made to the four variants of the original are listed below:

Klezmer ver. 2

- The chord sequence is not automated, which means that the performer will have to change the chord manually, thereby getting more possibilities both to change the timing if performing the song, or to play the chords in a different order.
- The rhythmic patterns that were defined in three of the instruments are changed to straight note values.
- A video of this is found in an online repository [17].

Klezmer ver. 3

- No randomizations at all in the pitch material.
- A fully recorded version of both the cursor controlling the instruments and some of the sliders, for instance the one controlling the tempo. Hence this version can be used to play back this song completely without any further input after it starts. But it is still interactive to a certain extent since it is possible to override the recording by interacting directly with the sliders or the cursor. When released they will go back to the position in the loop where they would have been without the override.
- A video of this is found in an online repository [17].

Klezmer ver. 4

- The chord sequence is not automated, which means that the performer will have to change the chord manually, thereby getting more possibilities both to change the timing if performing the song, or to play the chords in a different order.
- Added randomizations on the pitch material so that there is a certain amount of randomization at any given moment.
- A fully recorded version of both the cursor controlling the instruments and some of the sliders, for instance the one controlling the tempo. But since the chord sequence is not automated, this version cannot be used to play back this song completely without any further input after it starts. And even though the cursor and the sliders are automated, they are still interactive to a certain extent since it is possible to override the recording by interacting directly with them. When released they will go back to the position in the loop where they would have been without the override.
- A video of this is found in an online repository [17].

Klezmer ver. 5

- The rhythmic patterns that were defined in three of the instruments are changed to straight note values.
- A video of this is found in an online repository [17].

V. Conclusion

The concept of a DMI characterized by affordances that are situated in a field between those typical of a playable instrument and a pre-composed piece of music is a relatively new one. When using the possibilities of the Gestrument Engine to map the Musical Interactivity Area, it has become clear that the model is useful to describe this field, even though it is done in parallel to mapping out the model itself. To visualize different settings in an area focused on these specific aspects might be beneficial not only to interactive technologies like the Gestrument Engine, but also to the larger field of research and development of DMIs, future strands including SMIs, as well as Virtual Reality (VR) and Augmented Reality (AR) experiences. When composing and designing the musical experience of interactive artwork in these domains, the model of the Musical Interactivity Area might be a beneficial analytical tool.

The inherent possibilities of interactive DMIs are potentially fundamental for the future of music, both regarding music creation, music performance and music consumption. While interactivity often has been an important component in the arts across the centuries, and has taken many different shapes, today many examples are coming from video games. Since the concept of the video game is becoming more and more generic and is now influencing everything from educational tools to musical performances, aspects of interactivity in music will probably become paramount to the future of music. When considering that many trends in the commercial world points towards more focus on simplified personal creativity—through tools like Instagram, TikTok and Roblox—the development of DMIs that navigate a field between the pre-composed and the personal expression in performance, for musicians and nonmusicians alike, constitutes a possibility worth pursuing.

While conducting this research, the discussions between Martin Fröst and Jesper Nordin has been focused both on the musical and artistic possibilities that arise when a soloist meets an emerging technology, but also on the possibilities regarding new ways for an artist to interact with an audience. When using a technology like the Gestrument Engine to set the confines of the input data like it is done in the video with Martin Fröst and Jesper Nordin [16], one can easily imagine a situation in which the artist plays their part of the music in one location, while each online audience member produces their own, individual accompaniment. Network performances and the possibilities of IoMt have become even more relevant in the light of recent developments in society due to the current pandemic, and many artists are looking for new ways of interacting with audiences through internet in ways that are more meaningful than just streaming. Hence this technology, and others pointing in the same direction, might make for relevant future research topics in the field of SMIs, IoMt and network performances.

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