Post-DMI musical Instruments

Conference Paper · October 2016

DOI: 10.1145/2986416.2986440

Amelie Hinrichsen

Universität der Künste Berlin

Post-DMI musical Instruments

Amelie Hinrichsen
3DMIN
Universität der Künste Berlin
a.hinrichsen@udk-berlin.de

Till Bovermann
3DMIN
Universität der Künste Berlin
t.bovermann@udk-berlin.de

ABSTRACT

What are the particularities of developing contemporary instruments? This text points out how the authors observed both a focal shift and persisting elements in the design of contemporary digital musical instruments (DMI's). Based on observations around selected instrument prototypes that were developed by students as well as the authors, four constituent aspects of the development process of hybrid instruments emerged: corporeality — the role of the body, materiality — the role of material, sound — the instrument's sonic appearance, and control — its behaviour.

CCS Concepts

•General and reference → Design; •Applied computing → Sound and music computing; •Human-centered computing → *User interface design; Scenario-based design;*

Keywords

Musical instruments; Instrument development.

1. INTRODUCTION

3DMIN is an interdisciplinary research project between UdK Berlin and TU Berlin. Within this context, associated researchers and students have built a broad range of tools to make music: the 3DMIN instruments [4]. After 2.5 years of production and investigation, we reflect on the project's tangible outcomes in this article. Early in our process we found out that, since instrument making involves extensive testing, the makers turn into a kind of hybrid, a "performer-developer" [6]. The design and reflection process draws particular intention on playing, primarily in an improvisational context since there is no composition for the instrument-in-the-making (yet).[1] Supported by an open-ended design process and by encouraging variety in the intended musical aesthetics, the emerging instruments appeared to integrate acoustic, electronic as well as digital aspects. They turned out to be hybrids, in between classifications. They are therefore clearly separable from digital musical instruments (DMI's), commonly translated as digital music instruments/interfaces. While "the Digital" plays a central role in DMI's, they focus primarily on controlling and playing (with) it,[2] the 3DMIN instruments integrate it as a mere material and mechanism, just as wood, cog-wheels or living tissue. Instead, constituting elements of these post-DMI instruments are both their reference to and engagement with aspects of materiality — the role of material, corporeality — in a phenomenological and performative context, sonority — the instrument's sonic appearance, and control — its emerging behaviour. The subsequent sections introduce the different instruments (Section 2) and discuss how they can be put into relation to the aforementioned contexts (Section 3). Section 4 summarizes and introduces a post-DMI instrument's blueprint according to its four constituent aspects.

[1]"We do not study phenomena from a disengaged distance. Rather, we must proactively engage in making new instruments" [8, p.76]

AM '16, October 04 - 06, 2016, Norrköping, Sweden

ISBN 978-1-4503-4822-5/16/10...$15.00

DOI: http://dx.doi.org/10.1145/2986416.2986440

2. INSTRUMENT OVERVIEW

The following paragraphs provide short overviews on a selection of ten instruments developed by students and researchers within the scope of the 3DMIN project. Details and documentation videos can be found at the links provided in the respective footnotes.

2.1 Organum Vivum

Figure 1: Organum Vivum

[2]In terms of musical interaction Cadoz criticizes the lack of 'physical (ergotic) meaning' in many DMI's [5, p.227].

Aliisa Talja and Paul Seidler — Organum Vivum is a home grown instrument. Its control elements consist out of three pieces of cellulose bacteria. It is an interspecies interface advantaging the characteristics of organic material as well as exploring the possibilities of combining natural and build organisms in sound synthesis.[3]

2.2 Entangle

Figure 2: Entangle

Katharina Hauke — Entangle combines feedback and voice. This setup attaches a microphone to one a speaker to the other hand. Four fingertips are connected to the fingertips of the other hand by elastic straps. By speaking, whispering or singing into the microphone samples can be recorded and further processed according to the distance of the fingertips. The speaker in the other may or may not produce feedback in combination with the microphone.[4]

2.3 S/A/S/A

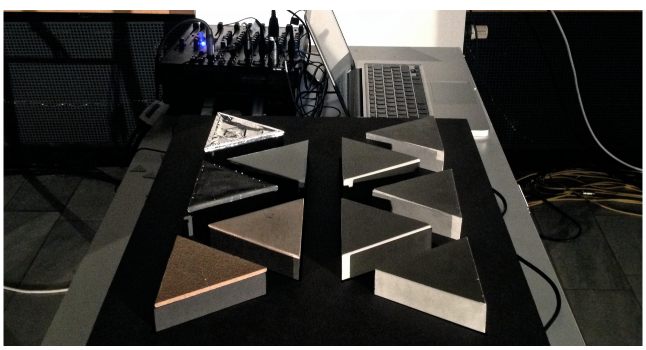

Figure 3: S/A/S/A

Julius Fischötter — S/A/S/A consists of 10 triangular blocks, five made of concrete connected to capacitive sensors, the other five wooden, each with a unique material on top (e.g. cork, aluminium film, sanding paper) and a contact microphone inside. S/A/S/A uses direct audio input as its source and is played by two musicians. While one articulates sounds by scratching and stroking the different materials on the blocks, the other modulates parameters of effect sets by touching the concrete block.[5]

[3]http://www.3dmin.org/organum-vivum/
[4]http://www.3dmin.org/entangle/
[5]http://www.3dmin.org/s-a-s-a/

2.4 SUM 0.2

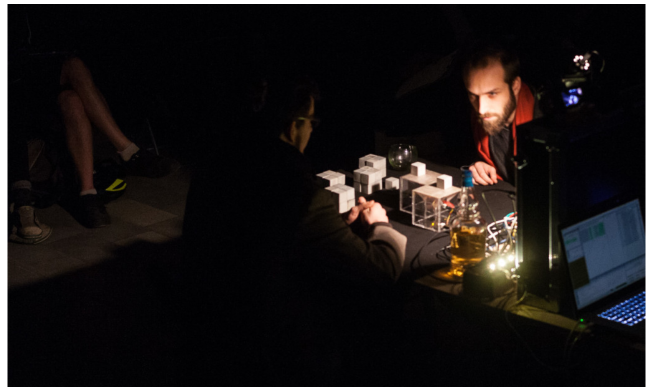

Figure 4: SUM 0.2

Nikolas Lefort and Jonas Hummel — Sum 0.2 introduces the idea of playing a modular synthesizer as if playing a game. A feedback matrix made of capacitive sensors controls a modular synthesizer. Values change according to the amount of concrete cubes set upon. In that way a Sum 0.2 performance reminds us on two people paying chess with each other.[6]

2.5 Surface[2]

Figure 5: Surface[2]

François-Xavier Loucheur, Maximilian Buske, Ludwig Voigt, Gabriel Treindl, and Wolfgang Kick — A modified drum is equipped with a ceramic disc on top. Direct audio input as well as capacitive sensors form the structure of this instrument. Played with three setup made of a same kind signals can be chained and feedback further processed.[7]

2.6 Euclidomat

Ruben Layer, Gabriel Treindl and Maximilian Buske — The Euclidomat is a drum machine using algorithms for creating euclidean rhythms and solenoids to strike an interchangeable selection of resonating objects. It is an indirect

[6]http://www.3dmin.org/sum-0-2/
[7]http://www.3dmin.org/surface2/

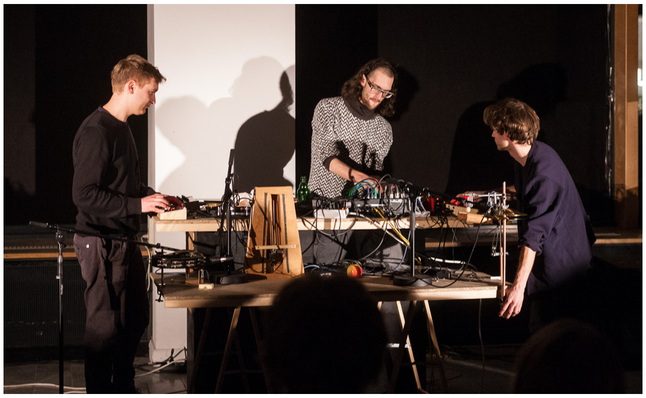

Figure 6: Euclidomat

setting where the musicians arrange the flow of the performance by occasionally interfering with the running system. This can include changing speed, parameters of the pattern generator, and changing both the positions of the solenoids, and the resonating objects.[8]

2.7 PushPull

Figure 7: PushPull

Dominik Hildebrand Marques Lopes, Amelie Hinrichsen and Till Bovermann — PushPull's central control element is a bellow combining inertial sensor data with mechano-analogue sound input (breathing of the bellow) which can be freely combined with digital synthesis [12]. Its current collection of implemented playing modes ranges from melodic sounds to complex feedback structures played with meta-control strategies.[9]

2.8 Tensegrity, Half-closed loop

Till Bovermann — Audio feedback and control play the central role in the design of Tensegrity and Half-closed loop [3]. By means of inducing feedback on various levels — particularly by custom parts consisting of a string in a brass pipe and a wooden board with attached structure-borne drivers (Half-closed loop) or a tensegrity structure made of wooden bars and e-bass strings with attached sound transducers and actuators — their design does not only allow the performer to produce a broad range of musical expressions but also integrate elements of instability into the performance. As an open system with a significant amount of complexity in

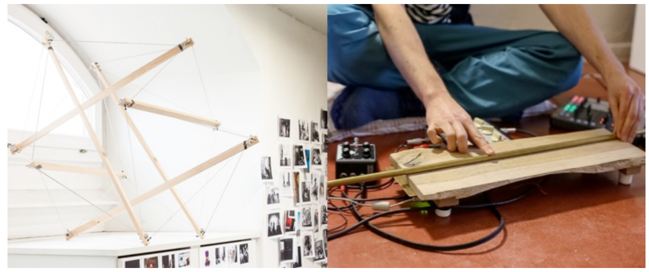

Figure 8: Tensegrity (left), Half-closed loop (right)

routing and control, the system "fuses" performer and instrument into a "meta-system" of human-instrument entanglement.[10][11]

2.9 Wavesetter

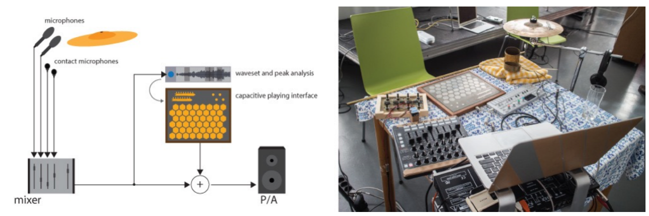

Figure 9: Wavesetter

Till Bovermann — WaveSetter is an electronic instrument designed to facilitate re-synthesis of real-time captured sounds by means of WaveSet analysis [23]. By the press of a button, the instrumentalist samples the last two seconds of live sound material originating in acoustic and analogue-electronic sound sources of her choice. This material is then analysed for zero-crossings and transient peaks. Transients are subsequently assigned to the capacitively sensitive pads of a Manta controller [20] from which the musician can trigger their playback to accompany her performance.[12]

2.10 Impro Instruments

Figure 10: Impro Instruments

Amelie Hinrichsen in collaboration with Lea Danzeisen, Tobias Purfürst, Joshua Rutter and Till Bovermann — The Impro Instruments are a set of two visually very different

[8] http://www.3dmin.org/euclidomatics/
[9] http://www.3dmin.org/pushpull/
[10] http://tai-studio.org/portfolio/halfClosedLoop.html
[11] http://tai-studio.org/portfolio/tensegrity.html
[12] http://www.3dmin.org/wavesetter/

artefacts. While one originates in a series of improvisational investigations with balloons, the other has its roots in similar investigations with cardboard tubes. Both instruments incorporate direct audio input and use various sensors to control their sonic output. Their sound engines feature loops, delays, direct and filtered sounds.[13]

3. INSTRUMENT ANALYSIS

We differentiate four contexts between which the design process of contemporary instruments oscillates: corporeality, materiality, sonority, and control. In this section we briefly introduce our interpretation of them and exemplify their aspects by the instruments described in Section 2.

3.1 Materiality

Context.

Sennett introduces the question of what makes an object interesting to avoid getting lost in a philosophical forest: "we become particularly interested in the things we can change." [19, p.120]. He explains that changing an object revolves around three *key issues*:

Metamorphosis i.e., switching techniques,[14]

Anthropomorphosis i.e., imputing human qualities to a material, and

Presence i.e., leaving a mark.

Those issues form the three types of material consciousness. Founded on psychological encounters, Sennett further states that "the idea of the 'transitional objects' more largely names what can truly engage curiosity: an uncertain or unstable experience." [19, p.158].

Materiality therefore has the power [2, 17] to form the basis of the musicians engagement with her instrument. Further we are convinced that the instrument's materiality play a major role for the experience of a musical performance, thus strongly contributing to audience engagement.[15] Consequently, the conscious use and preservation of acoustic material characteristics produce *material authenticity* [13], a term that may serve as a *Leitmotiv* during the design process of post-DMI's to create an instrument with individual audio-visual character.

Exemplification.

The interest in materiality is apparent in several of the 3DMIN instruments:

Entangle's elastic straps, e.g., introduce a freedom of movement that renders crucial and characterising for its expressivity. In interplay with the instrumentalist's hands, they define the scale and possible shapes of micro-acoustic cavities that in turn constitute the instrument's inherent sonic character. Everything in Entangle is interconnected, creating a constant experience of instability.

In their development, both Surface^2 and S/A/S/A traversed, i.e. *metamorphosed*, by material studies to their inherent sonic characters: porcelain surfaces with different structures and hence acoustic properties in the case of Surface^2; amplification of interaction with cubes of raw material (cork, wood, sanding paper) in the case of S/A/S/A.

Organum Vivum again introduces various forms of instability by deploying self-grown bacterial cellulose as its main playing interface: The living interface and therefore the instrument itself thus becomes sensitive to humidity and temperature, subtle differences in touch produce variations in its sonic gestalt. This is in direct contrast to PushPull where the design of the bellow settled on a stable and sealed yet flexible and light construction only after an extensive and time-intensive exploration phase. Both the bellow's form and the physical properties of the aoir valves introduce limits of the instrumentalist's arm movements and therefore provide the framing for the instrument's sonic capabilities, creating a substantial impact on its sonic character.

The Impro Instruments, finally, took materiality as one of its starting points by introducing raw materials as constituting form into the co-designing process. Playability and sound concept were consciously informed by the notion of material authenticity mentioned above. The Euclidomat demonstrates this kind of authenticity on a different level. While a complex algorhythm creates polyrhythmic structures direct acoustic signals equip the setup with an immediate and recognizable level of sound generation.

Conclusion.

In all these cases, the physical properties of the materials used had a strong influence on the design decisions made during the development process and informed emerging playing techniques and sonic output. We found that the use of material took one of three directions:

Material as limitation Material qualities constitute the freedom of movement and range of values (Entangle and PushPull).

Materiality as inspiration The development process was highly inspired by exploring material qualities, either of one specific material (Organum Vivum, Surface^2) or on a range of materials (S/A/S/A).

Material as link Recognizable sound qualities linked to the visual appearance of the instrument, creating a sense of material authenticity (Impro Instruments, Euclidomat).

3.2 Corporeality

How differentiated, nuanced and music shaping is corporeality? What is its influence in an improvisational instrument development context?

Within the field of musical instrument design, corporeality is closely linked to touch, which clearly originates in STEIMs tradition where it was one of the foundations on which electronic instruments were developed. This becomes immanent e.g., in STEIM's event series "Touch-Exhibition" [15, p.115]. Seven out of the ten described 3DMIN instruments share touch as a constituting mode of interaction.[16]

---

[13] http://www.3dmin.org/impro-instruments/

[14] An example from pottery would be e.g., from using a mold to form a vessel to turning it on a potter's wheel.

[15] "It is clear that neither bodily movement nor sound alone tells the whole story with regard to the perception of music performances." [11, p.168].

[16] These are Entangle, Surface^2, PushPull, the Impro Instruments, S/A/S/A, Half-closed loop and Organum Vivum.

For further discussion, we examine touch from two different perspectives: as a physical interaction and as a performative element towards audience engagement.

3.2.1 Touch and being touched by the instrument

Context.
Merleau-Ponty does not consider body and mind as separated entities. For him playing an instrument serves as an example for a non-reflexive, embodied knowledge at which the inseparability of body and mind reveals itself [16, p.175]. This goes along with Sennett's elaborations on grip: Within American slang, "getting a grip", e.g., refers to the notion of understanding and is, on an evolutionary perspective, closely linked to the use of tools [19, p.151]. This argument is supported by Jeff Carey, who used the same expression when explaining his reasons to swap his live setup from a standard computer to a selection of game controllers, performing with the computer to his side.[17] According to Sennett, another quality of touch as direct physical contact is the simultaneity of proactiveness and reflectiveness [19, p.151]. Something Waters is also concerned about when introducing his notion of the performance ecosystem.[18]

In this context, physical contact extends beyond the fingertips. Kim introduces e.g. the moment when the instrumentalist's body resonates along with the instrument's body, thus affecting the experience of making music [15, p.110]. Further, Kim explains that the musical instrument enables musical experience through embodiment because it couples audio with tactile / kinesthetic feedback [15, p.114].

Exemplification.
We observe touch as a way of sonical and physical exploration in Organum Vivum, Surface^2, and the Impro Instruments.

Conventional approaches of interacting (touching) —pushing a button, turning a knob, or moving a slider— were mimicked by alternative approaches of direct contact: From pinching and stroking a surface (Organum Vivum) to attaching elastics to fingertips (Entangle). Surface^2 invites the player's fingertips to explore different qualities of surfaces while the touching element in S/A/S/A ranges from interactions with one finger to engaging with the complete hand.

Touch can even get bigger than the size of the hands: Half-closed loop transmits physical vibration into the musician's arms and body, creating resonance and feedback on multiple levels. Contrastingly, PushPull invites to engage arm and upper body to push and pull against air resistance, thus creating and directing its characteristic sounds. We experience here embodiment generating knowledge in a concrete, attached manner, based on Kim's kinaesthetic experience.

3.2.2 Being touched by the performance

Context.
Within the complexity of a performance ecosystem or ecology [21], touch may also denote a non-haptic experience caused by the performer's presence and expressiveness. This does not necessarily imply an extroverted playing style but rather that the musician appears to be immersed within her playing. The "nervous feedback" between musician and audience that Carey mentions originates in the idea of one body resonating within the other [18]. Such assumptions, often described as "the magic of the theater' (and) the 'energy' that supposedly exists between performers and spectators in a live event" [1], are critizised by Auslander due to their unreflectiveness. Yet he admits "I came to see that concepts such as these do have value for performers and partisans of live performance. Indeed, it may even be necessary for performers, especially, to believe in them."[19] In line with Nass, Moon, and Dixon, he concentrates on the role of the spectator when it comes to the definition of what is live instead [1, p.9].

"[D]igital liveness emerges as a specific relation between self and other, a particular way of 'being involved with something.' The experience of liveness results from our conscious act of grasping virtual entities as live in response to the claims they make on us." [1, p.10]

Conversely this means: even when recorded material is being used in a live performance (as in digital music making, e.g., with loopers and samplers) it is about communicating that *something is live* with the goal to engage both audience and performer.

In the 3DMIN instrument performances, qualities of presence varied a lot, yet there was a strong sense of close relationships on a corporeal level between performer and instrument inherent in each project. We observed more traditional ways of interacting on stage with the instrument during the Euclidomat performance. In their playing, the three musicians switched between changing settings on their interfaces and physically grasped into the sounding objects while they were triggered by solenoids. Every once in while, the players exchanged looks, pausing their actions and listening to the currently evolving rhythmical patterns. The same level of interaction and readability was present during the S/A/S/A performance. Both musicians faced each other. While one hit and stroked amplified blocks of different types of materials, the other kept constant contact to a set of concrete blocks, thereby controlling filters and effects. In the setting of Sum 0.2 the audience turned into observers of a turn-taking game played by two musicians. Actions and sonic output could not be related directly to each other but actions clearly introduced changes in the sound process. Within Entangle and Organum Vivum, performance mappings were even less obvious. Yet each performance created a unique atmosphere which drew the audience' attention and interest possibly due to the performative triad of body, instrument and sound generation.

[17] Carey said: "Feeling like a piece of office furniture on stage was unrewarding enough to push me to have a physical grip on my sound."

[18] "[T]he specificity of an individual's 'touch' [...] results not only from the physiology of the player, but the complex feedback into that player's body of vibrating materials, air, room, and the physiological adaptations and adjustments in that body and its 'software' which themselves feed back into the vibrating complex of instrument and room." [21]

[19] This is underlined by various statements of contemporary musicians like e.g. Jeff Carey who reports that after getting away from the desk and the computer out of sight he got much stronger reactions from the audience. He further explained that performing with a computer drew so much attention on the screen that for Jeff as a performer, the audience is not existent. Without the computer the audience is "really in front of you" this changes the feeling one has. Audience becomes much more present and it comes to a "nervous feedback".

Corporeality: Conclusion.
It lies in the nature of music making that we are highly dependent on our senses to acquire knowledge on how to make and communicate music. The fact that instrument makers switch towards alternative ways to get in touch with their sound implies that the ubiquitous knobs and sliders are limited in the possibilities they offer for nuanced interaction. On one hand, this tactile approach in making music affects musical practice on a physical level, on the other hand, it affects the performer-audience relation, where it influences to what degree the audience experiences liveness. It turns out that movement and co-presence of musician and audience are crucial for this.

3.3 Sound

Context.
The range of sonic possibilities of an instrument, its sonic character, decides both how music played with it is perceived by the audience and in which context instrumentalists are likely to use it. An instrument with a diverse timbral repertoire may feature percussive drum-like sounds as well as sustained drones. Thus it can be played in situations that call for percussion (to impose structure) as well as, e.g., a low-pitched drone (to add a tonal anchor). Instruments based on sampling technology or acoustic feedback, on the other hand, can be used to pick up and extend sounds played by other instrumentalists. Altering sounds with filters and effects adds another layer of sound shaping. Here, time-affecting effects like artificial reverberation, echo and granular re-synthesis can be differentiated from sound-shaping effects like distortion, modulation or filtering. The combination of such electronic and digital sound making and shaping techniques with acoustic elements such as resonating bodies, airflow captured by a microphone or strings result in hybrid sound structures. Hybrid in two ways: they integrate digital elements with acoustics and they allow to include sonic characteristics from physical structures yet imprint it with artificially induced elements.
Orthogonal to the sonic ability of instruments are the demands imposed by musical genres. The recognition of an electronic music style, e.g., often relies on specific timbral elements: While acid house includes elements such as "exotic samples of birds, women speaking foreign languages, and drum machines", glitch music pieces are based on "sound of a digital 'mistake' that occurs through the mistranslation or deterioration of digital data" [7, 10]. Since instrument designers, consciously or unconsciously, imagine their instrument to be played in a certain setting, they guide its sonic capabilities towards that particular style.

Exemplification.
The acoustic properties of the signals captured by the microphones in PushPull are at times shaped by digital filters and effects, or used as a source for a feedback-delay matrix which creates spectrally rich pitched sounds. While the first strategy leaves times of silence (if the bellow is not moved, there is no sound), the latter easily results in a sustained wall of sound. An interesting difference in the sonic quality of two instruments with similar features in their materiality, control and corporeality can be observed in S/A/S/A and Sum 0.2: While the aesthetics towards which the instrument design for Sum 0.2 tend is clearly related to noise and drone music, the designer of S/A/S/A decided for rhythmical patterns and effects as they are iconic for in minimal techno. Wavesetter applies a digital synthesis process (WaveSet analysis) in real time to combine digital sound generation with direct audio input from DMI's as well as everyday objects.

Conclusion.
3DMIN instruments mix acoustic and digital sound generation because of freedom of the digital the identity-establishing quality of direct acoustic sound amplification.

3.4 Control

Context.
According to J.J. Gibson' s theory of affordances [14], every object is equipped with certain action possibilities — affordances. Following this thought, musical instruments exhibit such affordances that suggest particular modes of interaction.
However, "creating an instrument [...] is not only about the interface itself but the routines and patterns merging the object with the subject" [4] and, within the instrument itself, how parameters of sound synthesis are connected to control mechanisms. This implies certain levels of description for control mechanisms:

direct mapping every synthesis parameter is (within tuned ranges) mapped to controls accessible to the instrumentalist [22]

shared control synthesis parameters are mapped to controls accessible to several agencies. These agencies can be human, non-human, or artificial.

physical control manipulating the physical elements of a hybrid system changes its resonance and feedback properties, substantially shaping the sonic characteristics of the instrument.

automation parameter changes are delegated to semi-autonomous, pre-programmed processes like sequencers. Yet their behaviour can be changed and adapted by the instrumentalist via direct mapping.

metacontrol "gracefully relinquishing full control of the processes involved, in order to gain higher-order forms [of] influence on their behaviour." [9]

Many of the 3DMIN instruments rely on direct mapping. This might be caused by the limited experience of the instrument designers with more advanced processes combined with the relatively short timespan they allocated to control-design. An exception in which direct mapping was explicitly chosen are the Impro Instruments, in which —during the co-design sessions — it became evident that direct mapping supports the material authenticity, their constitutional element, tuning and discussed in the last co-design session.[20]
Another popular mapping strategy was automated and algorithmic control: While the turn-taking game interface

[20]Material authenticity necessitates immediate response to physical actions affecting the material itself (e.g. airflow inside the balloon setup whirling around small polystyrene balls).

of Sum 0.2 requires the sonic outcome of the instrument to be interesting enough without continuous interaction, the Euclidomat's central element is a generative mechanism that allows direct manipulation of timbre, while tempo and actual sound triggers are determined by its Euclidian series engine.

Both feedback and metacontrol were constitutional elements in PushPull, Entangle and Half-closed loop, however in different ways. Switching between available modes and playing styles of PushPull, e.g., requires a shift of attention towards the conceptual affordances the chosen sound offers, while its physical affordances, i.e., the physical constraints of the interface remain the same. Half-closed loop on the other hand offers a fluid interaction with an assemblage of physical elements that can be vibrationally coupled with each other. Thus the entire assemblage becomes an interface without predefined local functionalities; placing fingers anywhere or moving elements changes the physical properties of the feedback loop in complex manners, thus constituting metacontrol without explicitly being programmed into its software. Last not least, Entangle integrates both approaches: it's physical feedback system incorporates position, distance and hand posture changes into its physical appearance and therefore its inherent feedback system. At the same time, sensor data from hand movement and position modulate parameters of the electronic part of the instrument.

Gaining influence over an instrument rather than controlling it appears to be a constituting factor for post-DMI instruments: learning its sonic, material and corporeal character is supported by varying and constantly adapting control strategies. The level of understanding the instrument's elements varies among the 3DMIN instrument developers. Where some try to keep full control over the instrument, others abandon this idea and create an instrument that is capable to produce a broader range of expressions (PushPull, Entangle, Sum 0.2, Half-closed loop). Maintaining control may be motivated in trying to grasp the instrument at first. In a later step, this sense of control can gradually be given up. This hypothesis is supported by the fact that PushPull, the instrument with the longest development time, offers a rich variety of control mechanisms.

4. DISCUSSION

In this paper, we introduced the concept of post-DMI instruments and their constituting elements: their corporeality, materiality, sonority, and control.

We contextualized these elements and exemplified their usage at hand of the 3DMIN instruments, 10 instrument prototypes developed within the 3DMIN research project. We can characterize the design a post-DMI instrument by attention to the following four constituent aspects:

materiality physical properties of the used materials are included in the design process, e.g., as limitations, as inspirations, and as links.

corporeality the kinesthetic experience, movement and copresence of musician and audience are crucial to a post-DMI's experience. The computer's standard interface can be, and usually is, not needed.

sonority A post-DMI instrument mixes acoustic and digital sound generation. Inherent sound qualities based on direct acoustic sound amplification combined with both digital and post-digital filtering techniques convey its identity.

control The process of gaining influence over a post-DMI instrument is essential: learning to play with its sonic, material and corporeal character is supported by varying and constantly adapting control strategies within an iterative exploration process.

5. ACKNOWLEDGMENTS

We want to thank all colleagues and students of the 3DMIN project for their contributions, instruments and insights gained during intense discussions. Without them this work woyuld not have been possible. The realisation of the 3DMIN project, and thus this paper, was funded by Einstein Stiftung Berlin.

6. REFERENCES

[1] P. Auslander. *Liveness: Performance in a mediatized culture*. Routledge, 2008.

[2] T. Bennett and P. Joyce. *Material powers: Cultural studies, history and the material turn*. Routledge, 2013.

[3] T. Bovermann. Half-closed loop — an improvisation environment for covered string and performer. In *Proceedings of the ICLI 2016*, 2016.

[4] T. Bovermann, H. Egermann, A. Foerstel, A. Hinrichsen, D. Hildebrand Marques Lopes, A. Pysiewicz, S. Hardjowirogo, S. Weinzierl, and A. de Campo. 3dmin – challenges and interventions in design, development and dissemination of new musical instruments. In *Proceedings of ICMC/SMC*, Athens, 2014. National and Kapodistrian University of Athens.

[5] C. Cadoz. Supra-instrumental interactions and gestures. *Journal of New Music Research*, 38(3):215–230, 2009.

[6] B. Carey. Artefact 'scripts' and the performer-developer. *Leonardo*, 2016.

[7] K. Cascone. The aesthetics of failure:"post-digital" tendencies in contemporary computer music. *Computer Music Journal*, 24(4):12–18, 2000.

[8] L. Dahl. Designing new musical interfaces as research: What's the problem? *Leonardo*, 2016.

[9] A. de Campo. Lose control, gain influence - concepts for metacontrol. In *Proceedings of ICMC/SMC*, Athens, 2014. National and Kapodistrian University of Athens.

[10] J. Demers. *Listening through the noise: the aesthetics of experimental electronic music*. Oxford University Press, USA, 2010.

[11] M. Gurevich and A. C. Fyans. Digital musical interactions: Performer–system relationships and their perception by spectators. *Organised Sound*, 16(02):166–175, 2011.

[12] A. Hinrichsen, S. Hardjowirogo, D. Hildebrand Marques Lopes, and T. Bovermann. Pushpull. reflections on building a musical instrument prototype. In *Proceedings of the International Conference on Life Interfaces*, 2014.

[13] A. Hinrichsen and J. Schindler. Movements meets material. an improvisational approach to design. unpublished, 2016.

[14] G. J. Jerome. The ecological approach to visual perception, 1979.

[15] J. H. Kim and U. Seifert. Embodiment musikalischer praxis und medialität des musikinstrumentes-unter besonderer berücksichtigung digitaler interaktiver musikperformances. *Klang (ohne) Körper, Spuren und Potenziale des Körpers in der elektronischen Musik, M. Harenberg and D. Weissberg, Eds. Bielefeld: Transcript*, pages 105–118, 2010.

[16] M. Merleau-Ponty and R. Boehm. *Phänomenologie der wahrnehmung*, volume 7. W. de Gruyter, 1966.

[17] D. Miller. *Material cultures: Why some things matter*. University of Chicago Press, 1998.

[18] J.-L. Nancy and M. Fischer. *Die Ausdehnung der Seele: Texte zu Körper, Kunst und Tanz*. Diaphanes, 2010.

[19] R. Sennet. The craftsman. *Allen Lane,(trad. it L'uomo artigiano, Feltrinelli, 2009)*, 2008.

[20] J. Snyder. Snyderphonics manta controller, a novel usb touch-controller. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 413–416, 2011.

[21] S. Waters. Performance ecosystems: Ecological approaches to musical interaction. *EMS: Electroacoustic Music Studies Network*, pages 1–20, 2007.

[22] D. Wessel and M. Wright. Problems and prospects for intimate musical control of computers. *Computer Music Journal*, 26(3):11–22, 2002.

[23] T. Wishart. *Audible Design: A plain and easy introduction to practical sound composition*. Orpheus the Pantomime Ltd, 1994.