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Netz 2.0: Towards Site-Specific Performative Topologies

The way we perceive music, interact with musical instruments and produce music has changed. Based on new digital technologies and electronic and scientific concepts, musical instruments today differ fundamentally from traditional acoustic instruments. Thanks to micro controllers and a wide variety of sensors, there are no limits to the imagination when it comes to the design of new music instruments and interfaces for musical expression. However, this also raises new questions that go beyond the technical and sound-related evolution of interfaces for musical expression. How do we interact with these new instruments? How are they operated? Are approaches such as the traditional keyboard still a point of reference, or can the numerous possible interactions based on sensor technology and computer programming be formalised within a more contemporary classification? This article proposes a concept for analysing new musical interfaces and their interaction in a new light. It includes the description of the site-specific interactive sound installation Netz 2.0, which introduces a spider web-like instrument topology offering an interaction method based on stretching and pulling elastic strings.

1 INTRODUCTION - OLD AND NEW MUSICAL TOPOLOGIES

1. Bastian Maris' *Fire Organ*: https://www.vice.com/en_uk/article/aen7xe/dude-builds-flamethrowing-organ-blows-minds

2. Human Harp - 130th Anniversary Intervention, Brooklyn Bridge: https://vimeo.com/71960933

The creation of sound and music is closely connected to space. And as sound, also instruments themselves are often spacious, such as large organs with their high pipes, or Thaddeus Cahill's two hundred ton electronic *Telharmonium*. Another large instrument is Baastian Maris' *Fire Organ*[1], an arrangement of meter-high steel pipes in which gas explosions generate massive low frequency pressure waves, digitally controlled with just a midi-keyboard. Nowadays, even suspension bridges can become musical instruments, as implemented by the artists group *Humanharp*[2]. The *Global String* by Atau Tanaka (Tanaka 2001) is an instrument that even combines the physical and the virtual space. It reacts to vibrations, transports the information digitally through the Internet and reproduces it on a physical counterpart. Yet in all of those instruments and contemporary interfaces, interaction takes place via classical principles, like the plucking and bowing of a string, the striking of a key - musical interactions that have a long tradition, going back to string instruments such as the *Monochord* of ancient Greece or the traditional Chinese *Guqin* with a history of more than 3000 years or the African *Berimbao*. Instruments that use keys to be operated can be traced back to the *Hydraulis*, a 2000 year old Greek water organ. However, keys decouple the interaction from the sound generation and represent a tool-like extension. Those mechanisms of the instruments have become increasingly complex in correlation with technological developments. After all an essential step away from the key or string-based interaction was the development of electrophones, a new genre of musical instruments based on the use of electricity. Fascinating until today is the *Theremin*, an instrument played by the proximity of hands to two antennas. The interaction is based on the manipulation of electromagnetic fields without physically touching the instrument. Further new interactions are possible using e.g. the metal wire of Oskar Scala's *Trautonium* or the knobs and cable connectors of modular synthesizers, such as *Minimoog Model D.* Yet even Robert Moog had to add a keyboard to his *Minimoog* in order to attract the general public.
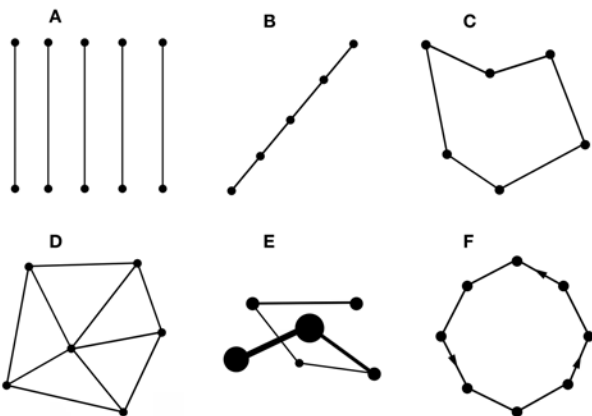
Fig. 1.
schematics of performative topologies:
(A) parallel topology, (B) axial topology,
(C) non-symmetric topology, (D) mesh topology, (E) three-dimensional topology,
(F) circular topology

3. Gametrak:
https://en.wikipedia.org/wiki/Gametrak

4. Leap Motion:
https://www.leapmotion.com/

5. Microsoft Kinect:
https://en.wikipedia.org/wiki/Kinect

6. PlayStation Move:
https://en.wikipedia.org/wiki/
PlayStation_Move

Nowadays, in digital sound production, it is the controller that links the musician and the sound production or data processing. Controllers can enable key-based interaction like the midi keyboard, fader- and knob- based interaction offered by midi control surfaces, but also three-dimensional string-based interaction with the *Gametrak*[3]. All these different controllers have in common that, depending on the controlled music software or the respective instrument, they can influence the sound generation in a freely configurable way.

Reviewing traditional forms of interaction, such as pressing keys or plucking strings, the physical aspects of the interaction between musician and instrument clearly shows a continuity towards modern controllers. The separation of the control unit and the sound generation, as in the case of the piano and the key, obviously still represents a convincing form of instrument design today and also remains adaptable to new developments and technologies. With modern technology, however, other types of musical interaction have also evolved, such as hand and finger tracking by the *Leap Motion*[4] or camera tracking using the Microsoft *Kinect*[5]. Being traced by the *Kinect* the entire human body and the surrounding space becomes a controller, even without physical contact to the control unit. The same applies to accelerometer-based devices such as the *PlayStation Move*[6] motion controller or the artistic *Gloves Project* (Serafin 2014). Musical interfaces that work on the basis of brain activity (EEG) completely detach the physical body from the process of sound generation. The potential of new technology seems to be endless, especially when the benefits of digital computing are reconnected into the physical domain, as Hiroshi Ishii and Brygg Ullmer suggested with the *Tangible User Interfaces* (Ishii 1997), in which physical artefacts are used to manipulate digital data representations in the computer.

If one considers today's totality of different instruments and musical interfaces, then the question arises how these can be described and categorised. One approach that might be useful is the concept of topology. The term is borrowed from the subjects of mathematics, geography and computer science and refers to relationships and systematic contexts. The first use of the term was made by the philosopher Johann Benedikt Listing, who in 1847 attempted to describe the Möbius band and thus reversibly deformed objects in general (Günzel 2007). In mathematics, for example, it describes qualities such as proximity and striving from one point to another or represents a set system of related subsets. In geography, the earth's surface is described based on three-dimensional data series. In electronics electronic circuits (circuit topology) are described with it. In computer science network structures are considered as topology. I would like to adapt the term to describe the configuration and the interaction of new musical interfaces and computer music suggesting the following performative topologies (see Fig. 1):

- **Parallel Topology:** traditional instruments such as the piano, guitar, violin etc. represent a parallel topology based on the string arrangement. Though also contemporary experimental interfaces such as the suspension bridge used by *Humanharp* can be considered as parallel topology.

7. Moritz Simon Geist - Sonic Robots:
http://sonicrobots.com/

8. SuperCollider:
https://supercollider.github.io/

9. Pure Data:
https://puredata.info/

10. P Jung in Jung - Thermospheric
Station: http://www.junginjung.com/
thermospheric-station

11. Seaboard:
https://roli.com/products/seaboard

12. Haken Audio:
https://www.hakenaudio.com/

13. Rhythm Ring: https://www.youtube.
com/watch?v=uKtisFD3PHE

14. BeatBearing: https://www.youtube.
com/watch?v=wreP8FMupyM

15. XOXX Composer:
http://xoxxcomposer.axelbluhme.se/
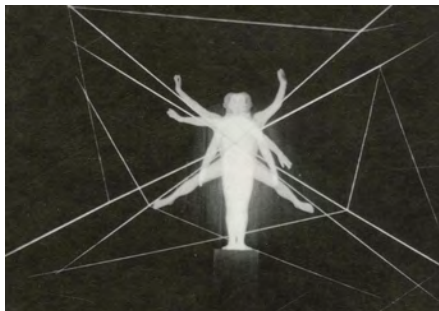
- **Axial Topology:** Instruments such as flutes or the *Glass Accordion* (1762) by Benjamin Franklin (Hermosa 2013) exhibit an axial topology.
- **Non-symmetric Topology:** an example for a non-symmetric topology could be the free arrangement of drums and cymbals in a drum set, of which Moritz Simon Geist's *Sonic Robot*s[7] represent a modern version. Likewise, the arrangement of the physical tokens on top of the *Reactable* (Kaltenbrunner 2007) or the physically engraved instrument scores at Enrique Tomás' *Tangible Scores* (Tomás 2016) could be considered non-symmetrical or open topologies.
- **Mesh Topology:** since the development of the electrical instrument a new topology appears: the mesh topology. It can be found in the networked modules of a modular synthesizer, in object-oriented musical programming languages, such as *SuperCollider*[8] or *Pure Data*[9], or even in the instrument design based on string controllers at Jung in Jung's performance project *Thermosheric Station*[10].
- **3D Topology:** Interaction based on pressure sensors and horizontal movement, e.g. *SeaBoard*[11] or *Haken Continuum*[12], could be described as a 3D topology. Likewise, projects like the *Schallmauer* (Tomás 2018), although based on physically solid material, allows touching and pressing for interaction and therefore also represents a 3D topology.
- **Circular Topology:** mechanical music devices whose playing principle is based on the turning of reels represent a circular topology, as well as other physical scores, such as barrel organs, music boxes or even band echo devices. This includes musical interfaces like the *Rhythm Ring*[13], the *BeatBearing*[14] or the *XOXX Composer*[15].

Fig. 2.
Oskar Schlemmer Delineation of *Space with Figure* (1927) and *Netz 2.0 at ACF London*

16. Wintergatan - Marble
Machine: https://www.youtube.com/
watch?v=IvUU8joBb1Q

These different topologies can also mix in specific cases, such as the *Wintergatan - Marble Machine*[16] project by Martin Molins. Here, driven by a winding mechanism (circular topology), hundreds of marbles are set in motion, falling on sounding materials that are both arranged in ascending order (parallel topology) and freely arranged (non-symmetrical topology). Nevertheless, the concept of musical topologies might be used to categorise a large number of new instruments, NIMEs and other artistic strategies for sound creation, such as the project presented on the following pages. It helps to distinguish them from each other, which can take place at the level of interaction, as well as at the level of sound generation.

2 THE NETZ 2.0 - A SITE-SPECIFIC INSTRUMENT

The *Netz 2.0* (see Fig. 2.) is a site-specific sound installation in the shape of a spider's web, which can be used as an instrument for sound generation by stretching its elastic strings. It is a musical instrument and an interactive sound installation at the same time. The visitor or musician can change and modify the structure of the net with physical force in order to create the various sounds. Developed in its first version in 2015 it received a major technical update in 2018. Following the previous thoughts on musical topologies and considering its physical arrangement and musical interaction, it represents a performative mesh topology.

2.1 Inspiration and Artistic Intention

The artistic inspiration for *Netz 2.0* as a musical instrument comes from different sources. It is influenced by modular synthesizers, that offer sound configuring using cable connectors. The resulting density of cables sometimes seems like a ‚network of sound streams'. Also, it is inspired by the *Theremin*[17] and its mode of operation, where the hands move freely and control volume and pitch by approaching two antennas. After all, it manifests parallels to playing drums, where physical interaction and physical exertion are the integral element of interaction. On an artistic level it is inspired by the geometric and performative space experiments of Oskar Schlemmer at the Bauhaus in Dessau, which he called *Mathematischen Tanz* or gestures dances (see Fig. 2.) (Goldberg 1988). Also the interactive dance and media performance *Apparition*[18] by Klaus Obermaier (Mocan 2013) had an influence. Obermaier's musical interweaving of space, movement and sound based on complex computer vision algorithms and a sophisticated set-up of projections also represents the use of space as an instrument. On the other hand, *Netz 2.0* is related to wildlife performances such as the spider's web, which is elastic, expansive and very resilient, especially regarding its geometry and thus is perfectly suited to catch prey.

17. Theremin:
https://en.wikipedia.org/wiki/Theremin

18. Klaus Obermaier - Apparition:
http://www.exile.at/apparition/
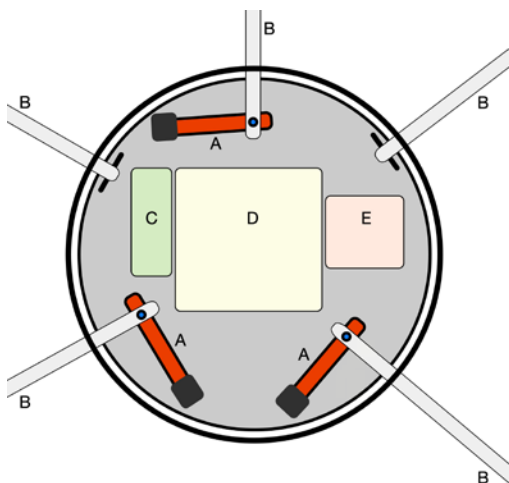
Fig. 3.
schematic: load cells (A), elastic strings (B), micro controller (C), powerbank (D), digital amplifier (E)

The combination of natural geometric forms and modern sensor technology addresses aspects of the ubiquitous use of technology. The *Netz 2.0* uses a mechanised environment as metaphor, becoming a kind of, environmental instrument'.

2.2 Force Sensing with elastic Rubber Tubes

On the technical side, the creation of a physical net structure that is elastic enough for interaction, but also capable of embedding available sensors and passing on their measures to a micro controller was challenging. Through tests with different materials the *Thera Band*[19] was identified as a suitable material.

Measuring the interaction with the material was more complex than expected. Based on design considerations, the data collection and processing should take place inside the center box, so the analog measurement signals had to be routed accordingly. In early tests conductive rubber cord stretch sensors[20] were inserted inside each rubber band to measure its strain resistance and read-out the user's interaction with the net, but the construction became very complex and fragile. The stretch sensors were quickly worn out and became unusable and the data acquisition was inconsistent and unreliable. Since the measurement of strain was not convincing, the next step was measuring the force applied to the individual strings of the net through force sensors, which consist of two components: the load cell[21] and the load cell amplifier[22]. The use of load cells has proven to be a suitable means of obtaining interaction data.

2.3 Software and Hardware Architecture

The following components are installed on the hardware level (see also Fig. 3.): main components are the load cells including load cell amplifier boards for force measurement. A *Teensy 3.2*[23] micro controller in addition with the *Teensy Audio Board*[24] and a Class-D audio amplifier board 2x15W including an external noise reduction filter between micro controller and audio amplifier are used. The audio gets played back from a waterproof loudspeaker 8Ω 20Watt. The power is provided by an USB LiPo Powerbank with 12V, 20.000 mAh, which has enough power to run the installation for two days. To power the micro controller a step-down converter is needed to convert the voltage from 12V to 5V. On the back of the box an On/Off switch is located as well as an USB socket to connect an external charging cable to the internal battery. The box is handmade of plywood and can only be opened by removing the loudspeaker. Attached to the box are 5 main strings of elastic tubes, each anchored in the wall and ceiling using hooks. Three of the five main strings provide force-measurement by sensors (see Fig. 3.). This decision is simply based on a lack of space within the central box, which left no space for additional sensors. The various elastic strings, that form the whole structure of the net, are attached to each other using

19. Thera Band: https://www.thera-bands.co.uk/

20. Conductive Rubber Cord Stretch Sensor: https://www.adafruit.com/product/519

21. Load Cell: https://www.sparkfun.com/products/13329

22. Load Cell Amplifier: https://www.sparkfun.com/products/13879

23. Teensy 3.2 USB development board: https://www.pjrc.com/store/teensy32.html

24. Audio Adaptor Board for Teensy 3.0 - 3.6: https://www.pjrc.com/store/teensy3_audio.html

metal rings with double, shortened cable ties, allowing easy readjustment of the whole net structure.

On the software side the micro controller processes the measurement data delivered by the three load cell force sensors. When the device is switched on, the load cell amplifiers calibrate themselves to a zero value. The calculation of the values also includes the calculation of the negative values that occur when the load cells are not loaded through interaction, but relieved. Additionally, in the software the sensors are regularly recalibrated when inactive. Furthermore, the load cell amplifier offers two working modes, a slow but reliable mode with 10 SPS (samples per second) and a faster but less reliable mode with 80 SPS. The *Netz 2.0* operates with the faster mode of 80SPS for reasons of response time, low latency and playability. The sound generation is based on simple waveforms like Sinus or Sawtooth provided the the *Teensy Audio Library*[25] and prepared sound files are played back using the *Teensy Audio Board*. The waveforms are altered in frequency or pitch depending on the stretching of the assigned strings.

To summarise, the hardware and software configuration of the instrument is very robust and reliable. This is due to the few but reliable hardware components used, the stable technical construction and especially the separation between the strings as a medium of interaction and the speaker box in the center as enclosure for the sensitive electronic components and sensors.

25. Teensy Audio Library: https://www. pjrc.com/teensy/td_libs_Audio.html

2.4 Interaction Design and Composition

Interacting with the *Netz 2.0* takes place by stretching, pulling or otherwise tensioning the physical strings (see Fig. 4.). While the entire net can be manipulated, the inner segments are particularly reactive due to the arrangement of the sensors in the center box. The entire structure can also be shaken. While stretching, a considerable physical force has to be applied that makes playing a very physical interaction, which, however, is also very responsive and produces immediate sound output. On a musical level, the moments of slight phase shift are most interesting, in which the three different waveforms begin to oscillate together.

Fig. 4.
Netz 2.0 - video still
(https://jensvetter.de/netz-lab30)
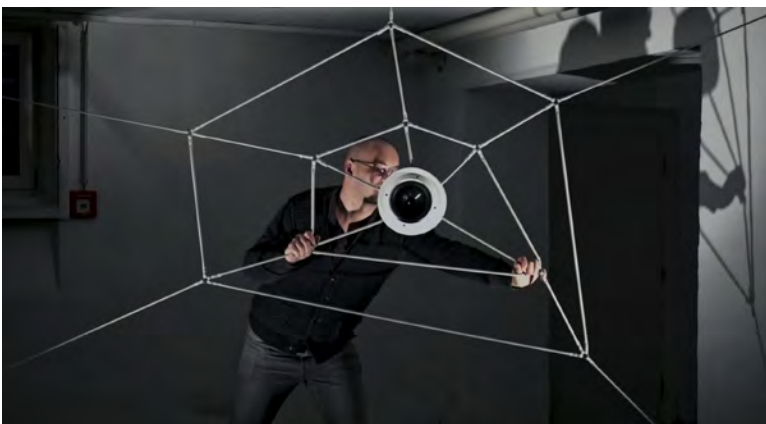
2.5 Conclusion

The *Netz 2.0* has been shown at various festivals and exhibitions, including Ars Electronica, Kiblix Festival, Digital Design Week London and LAB30. It was demonstrated on stage during a talk at TEDx Linz. The audience feedback was very positive, emphasising the fun of playing it. Especially children loved to interact with it. In the future, an update to the sound programming is planned, as well as an implementation of data output using MIDI or OSC to interface with external instruments in order to incorporate the *Netz 2.0* into a larger instrument setup for stage performances.

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