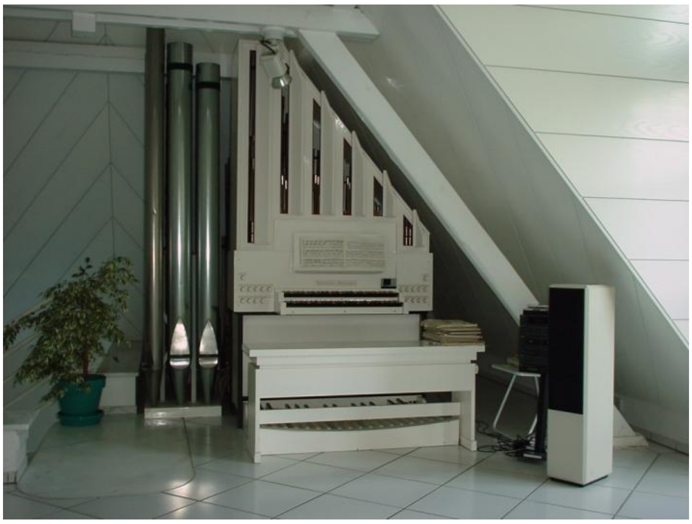
A STS Approach to Musical Cultures:

The Home Organ as Techno-Artistic Artifact

Technological Transformations of the Pipe Organ through Boundary Shifting



Supervisor:
Daryll Cressman
Peter F. Peters

Maximilian Matuschka
I6034150

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“But O, what art can teach
What human voice can reach
The sacred organ's praise?
[…]
When to her organ vocal breath was given
An angel heard, and straight appear'd
Mistaking Earth for Heaven”
(Quiller-Couch, 1919).

In his song for St. Cecilia's Day in 1687 the English poet John Dryden suggested that it was the patron saint of musicians herself who invented the organ. An ode to St. Cecilia from 1692 praised the organ as instrument "With That Sublime Celestial Lay" and as this "Wond'rous Machine" (Purcell & Brady 1692/ 1848, p. 2.). Indeed, before the Industrial Revolution, the organ, along with the clock, was a rare marvel of technological ingenuity. This went to such lengths that the famous German Jesuit Athanasius Kircher imagined the organ as fitting instrument for God’s creation of the world (Snyder, 2002, p. 1). Wolfgang Amadeus Mozart reports that a fellow musician was surprised to find the maestro asking to play on his organ as this monotonous instrument without ‘douceur’ and expression could not possibly be of interest to such an excellent ‘clavierist’. “All that means nothing” Mozart replied, “the organ is yet in my eyes and ears the king of all instruments” (1777, translation by me). Experiencing the pipe organ’s sound is sure to produce strong emotions.

Its history, its technological development and the need for the organist’s full body to put this machine to work permit seeing the pipe organ in its manifold variations as one of the most complex musical instruments in existence (Thistlethwaite, 2012). Additionally, due to the instrument’s size, cost, and power, organ performances are usually thought of as taking place in public settings such as churches, theaters or concert halls. How people transform the organ to be playable in a private setting and what that can tell us about corresponding musical cultures is explored in this paper by analyzing two case studies. Today, improved recording techniques and the increase in computing power have made virtual instruments an affordable alternative. As example the virtual pipe organ *Hauptwerk* will be studied. Another possibility is to build actual pipe organs of individual design at home. One case of a customized home pipe organ will be discussed in detail and then compared to Hauptwerk.

These two cases are analyzed to find out by which technological means the organ was adapted to its new context of use in order to better understand musical cultures of home organ innovation. Furthermore, the technologies materialized in the organ reflect the musical aesthetics prevalent at the time of its construction and use (Snyder, 2002, p. 18). Two main questions follow from this: What is understood to be the most important factor for original pipe organ sound and how is sufficient sound fidelity achieved to recreate the aesthetic experience of playing a classical pipe organ at home? The two examples will then be compared in regard to the dichotomy between the virtual and the acoustic by specifically looking at the technological means employed to recreate the original characteristics of sound generation, especially in connection to room acoustics. The theoretical framework builds on an STS perspective on music and on media studies.

The Pipe Organ as Techno-Artistic Artifact

Pipe organs can be seen as the paragon of the union between technoscience and the art of music. Sounds, and consequently music, need some sort of material basis to be created – be it a specific instrument, an everyday object or the human body. Focusing on the materiality of sound – on the science and technology of its machines and corresponding ways of knowing and interacting – Science and Technology Studies (STS) provide adequate tools to examine a highly technical instrument such as the organ and its modern developments in relation to specific cultural settings. The organ can be seen as technological artifact (Pinch & Bijsterveld, 2004, p. 638) or, more precisely, as artistic technology, "i.e. as a special kind of technology that is meant to produce aesthetic experiences" (Peters, 2009, p.6), thus bridging the gap between music and technology. Special attention is drawn to innovations and adaptations of the organ in attempts to recreate authentic pipe organ sound at home. In terms of co-production a STS perspective also takes into account other seminal actors in the network of sound generation, propagation and reproduction such as space, which, as we shall see, plays a major role in the (re-) production of pipe organ sound.

Considering their long history and the multiple changes experienced over the centuries, "organs have stories to tell about the times in which they were built that go far beyond the music that was played on them" and can hence be seen as "historical and aesthetic mirrors” of their time (Snyder, 2002, p. 1). Organs convey clues about why and how they “were designed and built, how they were meant to sound, and how they were part of musical practices” (Peters, 2009, p.5). What makes the example of the home organ particularly interesting is that, more than other instruments, the organ usually remains in one place throughout its life and becomes an integral part of the location’s architecture; even if examples like the Compenius organ remind us that some organs travelled and that the instrument was never solely intended to be played in a religious context (Snyder, 2002, p. 5).

Settings, or boundaries, within which these techno-artistic artifacts are developed and used, play an important role for this analysis. Virtual organs can basically be played anywhere – in both public and private settings – while the home pipe organ discussed here could in principal be used for small home concerts but never has – it is a private instrument for the personal pleasure of the organist only. Hence, the present cases are examples for a digital and an acoustic instrument that can both be played either for an audience or privately. Focus will be on the purely private use at home.

But settings or boundaries are relevant not only in a spatial context. Pipe organs almost demand some basic understanding of the physics of sound. As Snyder pointedly writes: “One can play the piano for a lifetime without ever giving much thought to the length of its strings, but one cannot sit down at an organ bench without being immediately confronted with the lengths of its pipes” (2002, p. 10). The crossing of boundaries, fusing the worlds of music and technoscience, helps explaining the emergence of different technological trajectories leading to sound fidelity. Discussing the development of the synthesizer and the changes made by Robert Moog, like connecting it to a conventional keyboard, Trevor Pinch and Frank Trocco have introduced the notion of boundary shifting. People like Moog, who was a trained electrical engineer with a strong penchant to music, not only

> “change identities, transgress boundaries, and move from one world to the other—say, from engineering to music—but they also apply the knowledge, skill, and experience gained in one world to transform the other. We call such people “boundary shifters”—people who cross boundaries and in so doing produce a transformation” (Pinch & Trocco, 2002, p. 314).

Successful innovation, it is argued, depends, at least partly, on allowing or even encouraging and facilitating such boundary shifting.

People involved in building, restoring, tinkering with, and playing the organ, seem to be predestined to this kind of interdisciplinary work. Analyses of the North German Baroque Organ project and the restoration of the Hinsz organ in Roden for instance showed that the research of craftsman, scientists, musicians and others did “not restore something that was already there, but can be seen as a form of continuous artistic innovation” (Peters, 2009, p. 16). The ‘restoration’ of original pipe organ sound at home – the technology behind sound fidelity – can be understood in similar terms.

Case Selection, Sources, and Methods

The cases at hand are understood to be examples of two different musical cultures. On the one hand there are people using different virtual pipe organs. *Hauptwerk*, which is the most prominent virtual pipe organ currently on the market, was chosen for this analysis. It is an innovative digital multi-purpose version of the organ and technologically very sophisticated when it comes to sound quality and diversity of offered instruments.

On the other hand, a quite versatile and resourceful Do It Yourself culture has emerged around the home pipe organ where people successfully combine their competences and interests to set up constructions of their own design at home. Examining a particular instrument as techno-artistic artifact allows insight into the nexus of organ music and technoscience in a private setting from the point of view of one person interconnecting both fields. In this case, the home pipe organ of an engineer and music aficionado will be analyzed in detail.

What makes these two cases comparable is that they can and are both used to recreate pipe organ sound at home but in different ways. The analytical comparison will focus on the material dichotomy between the virtual/ digital and the actual/ acoustic instrument. Emphasis is put on sound generation and the technological means to capture its characteristics, especially in connection to room acoustics. Equally important but going beyond the scope of this paper would be to examine the speaker systems used to eventually (re-) play the music.

Main source of information on Hauptwerk was the virtual pipe organ’s official homepage. Additional information was gathered on the website of Hauptwerk's owner, Milan Digital Audio, and the website of its greatest provider of sound samples, Sonus Paradisi. Unfortunately, direct personal contact with either the Hauptwerk team or Milan Digital was not possible (no reaction on mails; only online contact forms without phone numbers). According to the proprietor of Sonus Paradisi, competition among sample providers is considerably tough which is why no information going beyond descriptions found online could be disclosed. Furthermore, no contact details of the original programmer of Hauptwerk could be found. Therefore, a free trial of the test version and experiences reported by users on different online fora complement the data collection.

Apart from a rough virtual ethnography on different people building home pipe organs the main source of information on the chosen example of an acoustic home pipe organ was an extensive semi-structured qualitative interview[1] with Prof. Dr.-Ing. Puschner. To achieve maximum depth, richness and complexity the so called 'open the locks' model was successfully applied (Rubin & Rubin, 2005, p. 144). By respecting the rules of a responsive interview, thus creating a 'conversational partnership' (2005, p. 7f) much detailed information was gathered. The fact that I last saw the instrument in natura fifteen years ago is compensated by the amount of data collected during the interview and the granted access to the versatile documentation material taken during the construction process (technical drawings, pictures, sound samples etc.).

Each case is analyzed separately along the following lines. At first the 'virtual' and the 'DIY' communities are briefly introduced with a couple of examples in order to contextualize the main analysis. Then a brief history of the two instruments (although Hauptwerk is not strictly speaking one instrument, for sake of clarity the term is applied to both cases) is provided to better understand the developments. Next, the basic understandings of high fidelity pipe organ sound are examined and claims fleshed out. A close description of the technological features follows, focusing on how exactly views on high fidelity pipe organ sound are reflected in the two instruments' technology. Subsequently, both instruments are compared to find differences and similarities between an acoustic and a virtual pipe organ used in the recreation of realistic pipe organ sound. Finally, the results of the comparative analysis are explained by coming back to the notion of boundary shifting and then interpreted

[1] P. Puschner (personal communication, April 23rd, 2015)

using the concept of remediation and its twofold logic of immediacy and hypermediacy borrowed from media studies (Bolter & Grusin, 1999).

The Virtual Pipe Organ Hauptwerk

Technological improvements of the last decades, especially the continuously increased processing powers of computer systems, made virtual organs a welcome alternative for all kinds of people with an interest in music but no access to a real instrument of their own. Virtual pipe organs are available in different forms and qualities. Very basic examples are virtual keyboards on which different instruments such as the piano, the organ, the saxophone and the drums can be played (Virtual Keyboard). Also quite experimental is the *Mighty Miditzer Virtual Theatre Organ*, a free computer program that simulates a Wurlitzer Style theatre organ (Virtual Organ, 2013). More advanced software is offered by *GrandOrgue* (Grand Orgue) and the *Virtual Organ Company* even produces "digitally synthesized classical pipe organ modules that sound like the real thing" (Virtual Organ Company). Currently, however, one virtual pipe organ provider stands out. In 2001 the British programmer Martin Dyde started what was then called *Hauptwerk: The Virtual Pipe Organ Project* – a "generic computer simulation of a pipe organ…into which you can load different pipe organs and play them using a MIDI keyboard or keyboards" (Dyde, 2002). The name refers to the division of a pipe organ into different parts according to the so called *Werkprinzip*. Hauptwerk is the great manual or great organ, the instrument's main body where the most powerful sounds are produced.

By 2006 Dyde had founded Crumhorn Labs Ltd. in Birmingham – a crumhorn being a certain type of organ reed stop – and further developed the software of what was now officially called *Hauptwerk Virtual Pipe Organ* to version 2.0. Milan Digital Audio LLC with seat in Indianapolis, founded in 2002, started as provider of organ samples for Hauptwerk until it acquired Crumhorn Labs, and with it Hauptwerk, in 2008. Since then the company has put a lot of effort into making the actual 4.1.1 version the most praised virtual pipe organ on the market while continuing to produce "new and exciting virtual instruments from around the world" (Milan Digital, 2015, About us). Owner Brett Milan, musician and sound engineer, holds a double Master of Music in organ and piano performance and his commitment is probably not the least reason for Hauptwerk's success. Due to the instrument's digital nature it was not long before a lively and engaged international community of users emerged, exchanging views in all kinds of organ fora, on Facebook and on YouTube.

It is important to note that Hauptwerk is not one instrument but an online platform offering a varied array of virtual instruments – currently 174. Not only baroque, romantic, and symphonic church and theater organs from the last four centuries but even a couple of virtual harpsichords are on offer. Hauptwerk provides access for everybody from professional organist to interested amateur to a wide range of historical instruments via an intuitive and easy to use interface. Musicians have thus the possibility to "accurately perform a repertoire spanning centuries of organ music without leaving their living room" (Hauptwerk, 2015, Intro video). Sixteen companies, mostly from the United States and Europe, produce, sometimes exclusively, samples for Hauptwerk. Although a lot of sample sets are produced by Hauptwerk's owner, Milan Digital Audio, the main share of samples on offer are produced by Sonus Paradisi. This company with seat in Prague clearly stands out in its rigorous technological methods to make authentic pipe organ sound accessible.

Its mission is to record, document and archive "the sound of old and significant church pipe organs in the Czech Republic and in Europe, making them available for software samplers like Hauptwerk" (Sonus Paradisi, 2015, Project). Thereby, they not only offer playable 'images' to users but preserve historic pipe organ sound and make it available for scientists and amateurs alike. Because of striking overlaps and its importance for Hauptwerk, information from Sonus Paradisi, especially concerning their sampling methods, is included in the following analysis.

Sound fidelity

On the one hand the organ is an instrument that is hard to come by due to its cost and size. On the other hand "having unrestricted access to an instrument if not owning one is critical to being a successful musician" (Hauptwerk, 2015, Intro video). Hauptwerk sees it as its mission to bridge this gap, not only by providing the musician with 'his' instrument but also by offering the opportunity to play virtually on some of the most famous and historic pipe organs in the world, promising a "completely realistic playing experience" (Milan Digital, 2015, About us). Borrowing from Mozart, Hauptwerk is praised as "king of all virtual instruments", offering "worlds beyond digital" (Hauptwerk, 2015, main page). "Concert organists, students, church organists, studio musicians and Hollywood film composers" as well as other professionals utilize this sampler for their work (Milan Digital, 2015, About us).

Hauptwerk highlights that “room acoustics are a critical component of any organ’s overall sound” and claims to deliver “amazingly realistic sound” by using special sampling techniques (Hauptwerk, 2015, Intro video). The sound of a specific pipe organ, the 1738 Müller organ in the St. Bavokerk in Haarlem for example, can be realistically reproduced by utilizing recordings taken from real instruments, acknowledging the idiosyncrasies of each organ as well as the acoustic features of the location where it resides. “We believe that listening to a recording made with such a "virtual organ" in decent conditions can be really close to listening to the recordings of the original instrument” it is claimed (Sonus Paradisi, 2015, Basic info). This has been corroborated by several users such as Randall Mullin, who wrote an extensive report on his ‘Hauptwerk experience’: “Hauptwerk is not merely a practice organ substitute. The recordings made by performers on these "organs", called "sample sets" (a "sample" being a recording of one note), are very difficult to distinguish from recordings of the actual instruments” (Mullin, p. 2).

Although there are considerable differences in quality and complexity of sample sets produced by different companies and the three different Hauptwerk editions currently available (free, basic, advanced), the main argument for this claim of sound fidelity is put forward in terms of ‘wet’ sampling. ‘Dry’ samples are short recordings of only the pure tone without any ambient sound and can be used for performances in spaces with adequate reverberation. In contrast, wet sampling takes the whole instrument and its interactions with the room into account, creating much more nuanced results. In addition, Hauptwerk uses so called chromatic pipe recordings. Here, the sound of each and every pipe is recorded, allowing the realistic reproduction of all the nuances and character of any given rank. Every played note draws on a separate set of samples.

From sampling to audio output

As one of the most active providers of high-end sample sets for Hauptwerk, the following section describes the production of Sonus Paradisi samples. Basically, the audio software provided by Sonus Paradisi consists of a set of wave files, or samples, of single pipe recordings of between three and ten seconds in a resolution of up to 24 bit 96kHz plus metadata containing additional information about the ambient soundscape. These separate samples are then placed in subdirectories corresponding to the organ's individual ranks. Such recordings are furthermore divided into three parts: start (attack), middle (sustain) and end (release or echo). When a key is pressed the attack sample is played back, followed by a loop of the middle part. Releasing the key triggers the end part of the sample. To capture original sound most accurately a variety of "ambiental recording techniques" such as close up and multi channel surround recordings using the most advanced audio equipment are utilized (Sonus Paradisi, 2015, Project). In order to achieve maximum sound fidelity – particularly in regard to the church acoustics and the sonic interactions between the pipes – the company is currently developing a "sound holography 3D recording technique" allowing the collection and storage of information about the propagation of sound in a particular space (Sonus Paradisi, 2015, Basic info). To increase sound variation, sometimes multiple samples are taken of one pipe which can then be selected randomly by the sampler software, allowing an incredible polyphonic range (Milan Digital, 2014, Hauptwerk 4 features datasheet).

Some irregularity of organ sound is intended (and also unavoidable) with the real instrument and thus desired in the samples as well. Because they are believed to be a crucial part of authentic sound a great number of factors are taken into consideration: different properties of each pipe, interactions between all pipes, subtleties of the start and end of the pipe speech such as the initial and stopping transients, the fluctuation of amplitude and pitch, the pipes' response to the wind changes effected by tremulants, and the original reverberation – including the differences in the ambient response to long or short tones (Sonus Paradisi, 2015, Basic info). Meticulous attention is paid to details, right down to the mechanical action noises of draw knobs and keys as well as the blower sound and many other sounds commonly heard from pipe organs.

Besides the actual recording techniques, other technological innovations help to achieve the desired sound realism. *Release sample scaling*, for instance, scales a sample's release tail in volume to match the attack sample, allowing for natural sound when playing staccatos and short notes in general. Connecting more than one sample to one key of a certain rank makes the sound more alive because when a key is hit, a randomly selected sample is played back (*multiple sample support*). In some cases, one attack sample is equipped with several release samples to render the sound more natural. Dependent on the time a key is held, different release samples are played back, resulting in a much more accurate reverberation (*multiple release* *samples support)*. Additionally, a “multi-step procedure of denoising the samples” has been developed over the last years, assuring a “pristine and at the same time very clean and balanced sound” (Sonus Paradisi, 2015, Basic info).

To achieve sound fidelity not only the samples are important but of course also the way they are reproduced by the Hauptwerk software. Usually in response to a signal from a MIDI keyboard, Hauptwerk produces audio output based on the sample sets described above. Some technological modifications going beyond the basic playback of samples are offered by Hauptwerk to increase sound realism even further. *Harmonic filtering*, for instance, allows adjusting frequency envelope and volume by accessing the file’s metadata, simulating the effects of the organ’s expression pedal. *Physical modeling*, describing air movements through a pipe organ based on fluid dynamics, takes into account how wind pressure in the instrument affects pitch, volume and character. Again, by accessing the metadata of a sample set these parameters can be adjusted. It is also noteworthy that balance, pitch, voicing and many other sound parameters can be changed through the interactive control panels according to one’s personal tastes and actual setting.

The Self-Made Home Pipe Organ

There is an astonishing variety of DIY organs to be discovered. Some are very small, experimental organs, while others are surprisingly sophisticated and well designed. One example, an organ the size of two shoe boxes and equipped with a mini-fan and PVC pipes, simply emerged from the passion for music and the ‘urge to build things’ (Bugman113). Another interesting case is the development from a model with two wooden pipes and a vacuum cleaner engine to a playable instrument (Wandel). “I'm not an organist and I can barely play piano but I love music, organs and woodworking. Add to that that I'm a mechanical engineer and you have all the ingredients for a project like this”, says another enthusiast (Giangiulio). The result is a beautiful fully functional organ completely made of wood with mechanical action, one manual, one pedal, five ranks and 250 pipes. A French high school music professor studied mechanics, automatisms and musicology in order to fulfill his childhood dream of building an organ – an impressive mechanical pipe organ with two manuals, eight ranks and 422 pipes (Bélinguier). Now that we have gained a little insight into this community let us scrutinize a particular case.

Out of pure curiosity Prof. Dr.-Ing. Peter Puschner[2] visited the music fair in Frankfurt am Main in 1986. One of the exhibitors, the organ builder Hofbauer from Göttingen, had a novelty on display: a pipe organ construction kit for private residences. After playing on the instrument for a while Peter was approached by the proprietor. In the ensuing conversation factors like price, space, and experiences with electronic organs were weighed up and the possibility of owning a home pipe organ became an idée fixe.

Since his early childhood Peter has been captivated by music and electronics. He learned to play many instruments early on and even built his own sound studio with magnetic tape units and other electro technical gadgets. Becoming a sound engineer, which was his dream, would have required three years of piano training so he opted for electrical engineering. After earning his doctor's degree in mechanical engineering he took on a professorship at Paderborn University. On the sides he managed to pursue his interest in music and acoustic phenomena, working on reverberation frequency analysis in industrial complexes and churches. In 1972 he founded a company developing technologies for welding robots as well as "full electronic welding power sources for pulsed arc welding, high quality computer-guided TIG power sources for aircraft constructions and nuclear technology…" (Elmatech, History).

Two months after the visit to the music fair the Hofbauer organ kit arrived: one preassembled main console and many thousands of single pieces, including 744 pipes. Three days later the instrument was set up. Usually, this process takes weeks but Peter's professional know-how and the acquired knowledge from prior research on organ mechanics made the construction and installation a "Kinderspiel" – child's play. Pleasant anticipation is suspected to have added considerably to the remarkable swiftness of workmanship. In course of a little concert the organ was inaugurated with a performance by "Kirchenmusikdirektor" and "Domorganist" Herbert Voß, then organist of Aachen's minster.

Having taught himself to play the organ on his earlier electronic organ Peter knew that proper organ lessons were now unavoidable. For the next five years he was taught by Ulrich Peters, alumnus of Herbert Voß, on an instrument made by the Austrian organ builder Rieger for the St. Adalbert church in Aachen. The instrument and the acoustic conditions of the one thousand years old house of prayer allowed

[2] All following information on home pipe organ: P. Puschner (personal communication, April 2015).

the performance of a wide ranging repertoire and were thus felt to be the ideal that should be recreated at home. Taking lessons, Peter says, and the resulting friendship with his teacher gave him access to sheet music, literature, the wider organ community and, of course, almost unrestricted access to St. Adalbert's organ.

Sound fidelity

Sound fidelity is mainly understood to be a matter of sound generation and behavior. Idiosyncrasies of different pipes, their interaction with each other and the acoustics of the instrument's surroundings are paramount to original pipe organ sound. An actual physical instrument is considered to be essential to authentic sound generation while acoustic features of the room can be technically simulated to some extent.

All starts with the individual pipe carrying indelible traces of both the pipe caster and the person voicing it. The so called *transient* is the phase where the air column oscillates at the labium or reed until it stabilizes to produce a homogeneous tone. Depending on the pipe's overall measurements and especially those of its mouth, where the sound actually takes form, transients are different and influence the overall sound noticeably. Every pipe in its individual position is a separate sound source from which the vibrating air column is transmitted to the environment. In terms of interacting sound waves this means that the pipes 'know' and 'talk' to each other.

Another, often underestimated, sound source is the console itself. First, the oscillation build-up of a tone depends on the force used by the organist when hitting a key, which is in turn linked to the distinct key resistance of each organ. Second, the mechanisms running from the key to the valves in the wind chest also produce a certain soundscape. So even before the pipe responds a lot is going on in the organ, increasing the organist's tactile and immediate connection to his instrument.

Equally important as the actual organ is the space in which it is situated. An organist pressing a key is first hit by the direct sound coming from the corresponding pipe after which the waves spread out until they hit the next wall from which they are reflected and again meet the organist's ear. Reverberation depends on the surfaces and materials from which sound is reflected and on the signal's frequency (in church buildings, low frequencies generally reverberate longer). A multitude of reflections create a diffuse sound field that fades with a specific, frequency dependent reverberation time. Although not entirely understood, such acoustic phenomena were known and already taken into account by classical composers of organ music. The difference between direct sound and the diffuse sound field is usually only audible to the organist. It is particularly important that the room ‘carries’ the music because it allows taking the hands off the manual for a split second to change ranks without interrupting the musical experience.

Connected to this scientific understanding are more artistic claims and arguments centered on the already mentioned immediacy of the organist’s connection to his instrument. Playing on a pipe organ with mechanical action engages the organist in a direct conversation with his instrument. He has a direct connection between his fingers, the tracking action, the single valves, and even the coupling of manuals – all providing immediate feedback on his emotionally colored play. How an instrument reacts to the organist’s play, with resistance and delay, also has influence on tempo and caesurae: “Such feeling with the instrument is naturally impossible with a decoupled keyboard”.

In addition to this haptic experience, the fact that direct sound hits the organist from different sources around him evokes a feeling of sitting in the instrument, being enshrouded by music. This perception is usually amplified by the reverberation which depends on the room’s acoustic features and how they dampen and reflect sound waves. That sound is ‘being carried’ through a large room allows the “enjoyment of a cadence, when the room carries the chord after reducing key pressure, before the next chord sounds”. Being conscious of these factors the organist receives the continuous feedback necessary for his immediate connection to the events he controls from the console. In this sense, the musician, the instrument, and the room form a musical symbiosis – a beautiful union of science, technology and art.

Notably, language presupposing the organ as complex living being is often encountered in the literature. This metaphor of the organ being alive, it seems, can be linked to the scientific arguments about sound generation. The complexity of this process – the long evolution of the tone until it slips into the inaudible spectrum – invite this view. A pipe organ also needs air to function and slight variations in wind pressure have an effect on how the pipes ‘speak’, just like the human voice. Then there is the transient again, different for every pipe. Especially gedackt wooden pipes have a real life of their own until the tone is stable: they ‘cough’ a bit because wooden labia are not as sharp and the air column takes longer until it oscillates homogeneously. A sound’s antecedent is particularly distinct with low frequencies. Lastly, an organ lives from reverberation in the sense that the sound pattern is not interrupted during the transition from one sound event to another. From the point where a key is hit until the tone stands clear and clean: “There’s life in it!”

Playing and listening

These scientific and artistic arguments for sound fidelity are reflected in the small adaptations made to the original instrument and in the creation of a reverberating room by technological means. Being indispensible for authentic sound the basic instrument had to be a mechanical pipe organ small enough for a private residence while allowing the performance of a wide repertoire of mostly romantic music. Hofbauer provided such an instrument. The construction kit allowed building a pipe organ with two manuals, independent pedal and fifteen stops. In detail the organ consists of Hauptwerk (Prinzipal 8', Metallgedackt 8', Oktave 4', Gemshorn 2', Mixtur 2-fach 1 1/3'), Brust- or Schwellwerk (Holzgedackt 8', Rohrflöte 4', Oktave 2', Terz 1 3/5', Schalmei-Regal 8') and Pedalwerk (Subbaß 16', Pommer 16', Gedacktbaß 8', Choralbaß 4') with mechanical tracking action and the possibility to mechanically couple each manual to the Pedalwerk and the Schwellwerk to the Hauptwerk, each Werk using its own slider chest. Altogether there are 744 pipes; the wind pressure is 50 mm WC.

In order to achieve the best results some small adaptations were made. Tremulants varying the wind supply were installed into Hauptwerk and Brustwerk. The wind chests were equipped with a leaf-type spring to help regulating air pressure with no or low influence of the numbers of activated registers. Fitting the planned site the casing was constructed by taking advantage of the distinct arrangement of pipes and the inclination of the wall. Because it is often used in the romantic music that Peter likes to play, the casing was built as a swell box, allowing the dampening of tones. The largest pipes were positioned horizontally behind the organ and the whole casing was painted white, like the room. Placed in an average church this instrument would indeed sound like a classical church organ.

That being impracticable, how can a reverberating room be recreated artificially? To achieve maximum sound fidelity and out of professional plaisier the initial idea was to install something like fifty separate microphone-speaker systems into each wall, capturing the sound waves and replaying them almost instantly – a wall that reflects sound with the desired delay. Being a little too laborious another option was implemented. Microphones were installed at the top of the pipes, channeling the sound signal to a processor driven reverberation system with multi channel power amplifiers. Adjustable to up to five seconds reverberation time the signal is then emitted by loudspeakers in every corner of the room, thus simulating a diffuse sound field. Of course the damping behavior of the real room also plays a role, limiting the authentic recreation of that part of original organ sound that is created by the unique diffuse wall reflections of a certain building.

Boundary Shifting Audiophiles and Remediation

This section analyzes the virtual and the acoustic instrument's materiality and interprets findings in terms of boundary shifting and the twofold logic of remediation. The most striking similarity is that in both cases pipe organ sound is inextricably bound to the symbiosis of instrument and room. It is only through this union that a pipe organ sounds so unique and powerful.

> "Real pipe organs are designed and voiced for the acoustical space in which they're installed. Reverberant or 'wet' virtual instruments capture and reproduce the natural acoustic and spatial characteristics of the original organ's room, from each pipe's position separately. It's not just sampled acoustics, it's the real acoustics!" (Hauptwerk, 2015, main page).

Similarly, for Peter Puschner it is the generation of sound in a real instrument and its consequent propagation through space that brings the organ to life. This emphasis on reconstructing the symbiosis of instrument and room acoustics as crucial part of sound fidelity can be understood as being paramount to so called *audiophiles*. These "mostly white, mostly male, mostly affluent and educated consumers" of specialty audio equipment, also known as the 'high end', invest a lot of resources to satisfy their demands towards music (Perlmann, 2004, p. 783f.). What they are usually after when playing or listening to music on their sophisticated and often customized audio equipment is a strong emotional response. What is tried to be reproduced is thus something natural, dynamic, and lively. Recreating the pipe organ at home is the quest for an instrument that is imperfect, "a living-breathing entity that you can interact with and even fall in love with" (Pinch & Trocco, 2002, p. 319).

Fundamentally important to audiophiles is the most accurate sound reproduction humanly and technologically possible to preserve the 'unconditional sonic truth’. This, in turn, is understood as “the sound of live acoustic music being played in real space” (Perlmann, 2004, p. 789). How, then, can acoustic idiosyncrasies of pipe organs be recreated at home? With the virtual pipe organ actually many different organs can be played in their original environment. This is made possible through wet and chromatic sampling – multiple recordings of single pipes that take room acoustics into account. Hauptwerk also allows modifying certain sound parameters, enabling the organist to adapt his instrument to his taste and the respective setting in which Hauptwerk is used. Peter Puschner’s organ, on the contrary, is a single acoustic instrument to which the organist has to adapt. Nevertheless, the electronically adjustable reverberation time allows recreating a variety of locations. We can thus speak of a ‘hyperorgan’: “an organ with extended capabilities that seamlessly blend the electronic and acoustic worlds” (Harlow, 2011, p. 3).

Such transformations can be seen as being triggered by the boundary shifting of engaged audiophiles. Peter Puschner combined his extensive professional know-how about electrical and mechanical engineering with his interest in acoustics and his passion for music. Similarly, Brett Milan, the director of Milan digital Audio and owner of Hauptwerk, linked his know-how as professional musician with his knowledge about sound engineering to make Hauptwerk the most successful virtual pipe organ on the market. And Jiri Zurek, the man behind the biggest producer of sound samples, Sonus Paradisi, is affiliated with the Institute for Classical Studies at the Czech Academy of Sciences. However, only in Peter’s case enough gathered information supports this claim. Based on the analysis at hand a different shift is more apparent with the virtual pipe organ. Here, crossing the boundaries between the real and the virtual has actually led to the emergence of a whole new instrument that is much more versatile and adaptable to the organist’s individual situation. But however sophisticated the sampling is, signals corresponding to the singular pipes are already mixed electronically and reach the organist’s ear as one sound event emitted from the speakers. With an acoustic instrument sound waves come from different directions and only come together on the eardrum to produce a musical experience.

Let us now examine these techno-artistic artifacts from a media perspective in an attempt to understand why they took their respective forms. One way is to look into the respective aims and expectations of ‘users’. Hauptwerk is actually not one instrument but a digital multi-purpose tool with the purpose of creating an aesthetic experience in settings ranging from the own living room to recording studios to concert halls. Through its digital nature this medium can hence be used for public as well as for private performances in various locations and for multiple purposes. In contrast, the customized home pipe organ is a physical instrument and much more limited in scope. It is not as mobile or as versatile but it compensates this with its natural generation of sound. Furthermore it was intended for the sole purpose of the singular and personal aesthetic experience.

According to media studies scholars Bolter & Grusin "each act of mediation depends on other acts of mediation. Media are continually commenting on, reproducing, and replacing each other, and this process is integral to media" (1999, p. 55). ‘Remediation’ in this sense means the improvement or refashioning of media occurring in direct relation with other media and the respective cultural context. Remediation describes the way certain media are repurposed in order to convey an (emotional) experience as authentic as possible. Although the authors deal mostly with visual media, this idea seem to be transferable to sound fidelity in the study of music and musical instruments as well; particularly when technology is involved to such a large extent.

Two main concepts describe these processes of remediation. On an epistemological level *hypermediacy* describes the medium’s obviousness: the medium itself is an important part of knowledge gathering. Psychologically, the direct experience of the medium makes the whole experience more realistic in itself. *Immediacy* on the other hand has the psychological effect of providing a direct and authentic emotion without any detour. Epistemologically, immediacy means transparency – the absence of any visible mediation or representation. Both appeal to the unaltered authenticity of experience. Hypermediacy does it by multiplying and emphasizing the sources of information while the other, immediacy, tries to erase the medium completely.

The customized home pipe organ can be seen as achieving immediacy through the presence of the actual, physical instrument with its pipes and mechanics and the diffuse sound field being recreated around him through the microphone – reverb unit – speaker system. In contrast, the virtual pipe organ tries to compensate for the missing original instrument by merging separate elements like MIDI keyboards, graphic representations of consoles, speaker systems and of course the sample sets, creating hypermediacy in the process.

> "With version 4 of Hauptwerk, you can make your instrument as flexible as you wish: add as many generals or divisionals to the organ as you want; add missing sub and super couplers which the original organ doesn't have; switch keyboard assignments with the push of a piston; add four crescendo pedal settings to instruments that have none" (Mullin, p. 2).

In that sense, the virtual pipe organ becomes much more than a mere recreation of an original: it becomes an extended version of the organ which can be readily adapted to the organist's every desire and to the setting Hauptwerk is used in. The organist is aware that he is not playing on an acoustic organ but the illusion is so elaborate that it is accepted – not necessarily as real alternative to a church organ but rather as a whole new kind of multi-purpose organ. A techno-artistic artifact with many possibilities still to explore.

Conclusion

Examining the virtual pipe organ Hauptwerk and the customized Hofbauer home pipe organ as techno-artistic artifacts provided insight into the musical cultures that produced these transformations of the pipe organ so that it can be played at home. It has been shown that in both cases sound fidelity to pipe organ sound is inextricably linked to the symbiosis of instrument and room in producing the desired emotional musical experience. However, this common goal was achieved quite differently. Hauptwerk used so called 'wet' and 'chromatic' sampling as well as later manipulations of these sound files to make the sound of the virtual instruments as realistic as possible. In case of the acoustic home pipe organ room acoustics are simulated by means of high end audio equipment including microphones above the pipes, a reverberation unit adjustable to up to five seconds and loudspeakers evenly distributed in the room. The main difference to be observed is that in case of the home pipe organ the sound is generated by wind flowing through pipes like in classical pipe organs and only the room with variable reverberation times is simulated. Hauptwerk on the contrary employs complex sampling techniques and other technological sound modifications to simulate the original sound generation and propagation.

These particular technological innovations can be seen as being triggered by boundary shifting. Combining their professional know-how and personal interests (e.g. engineering and music), boundary shifters effectuate new ways for organists to play their instrument to which access is usually rather difficult within their own four walls. Furthermore, shifting from the real to the virtual has actually made Hauptwerk a whole new instrument – a novel techno-artistic artifact that the organist can adapt to his wishes, instead of adapting himself to the preconditions of a classic organ. Differences between the trajectories of the applied technologies can be seen in the light of media studies, hinting at the musical aesthetics of home organ enthusiasts. Hypermediacy is aimed at to compensate for the non-existent actual instrument and its sound generating pipes in the case of Hauptwerk, fulfilling the goal of rendering the organ experience authentic. Immediacy is attained through the combination of an acoustic instrument and its idiosyncrasies and the discrete technological simulation of a diffuse sound field. By thus combining a STS approach with media studies this paper has explored one possible mechanism generating technological innovations of instruments.

Taking a closer look at the two distinct communities of home organ enthusiasts would be the next step to improve our understanding of how transformations of the pipe organ occur. An intriguing place to start might be the Dutch company *Bovenschen Virtual Organs* who provides Hauptwerk software, keyboards, pedals, midi components, and touch screens. They even design and build complete casings for the use of Hauptwerk. Once more the boundaries between the real and the virtual are blurred by the organ – this wond’rous machine.

Note

For pictures, sound samples, external links and further material please consult the joint research project “Recreating Mucial Cultures of the Past for the 21th century” on the Research Catalogue (http://www.researchcatalogue.net/portal).

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Author's contact:

m.grafvonmatuschka@student.maastrichtuniversity.nl