The Just Intonation Automat – a Musically Adaptive Interface

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ABSTRACT

The first known dedicated music technology that was developed in Norway was an adaptive automat for just intonation made by Eivind Groven (1901-1977). In his work as radio pioneer, composer, musician and developer, Groven was mainly interested in folk music and its inclusion in the emerging modern society, and his inventions aimed at making just intonation commonplace in radio transmissions and church services, as well as in orchestral music. Groven's technology development had a musical rather than technical basis, and this article aims at explaining his motivations and aims while presenting the technical achievements in their contemporary context of the development of broadcasting and early electronic instruments. Paradoxically perhaps, Groven was uninterested in the possibilities for an entirely new music that electronic means allowed for, and which occupied composers working with electro-acoustic genres. Instead he wanted to promote the inclusion of a much older music paradigm in contemporary music – an interesting perspective for a music technologist.

The adaptive automat has since its first functioning version in 1947 been modernized twice, and currently exists in a digital and portable version. Thus, Groven's vision of making just intonation available to large groups of users has finally been realized, putting new composers in contact with this part of the world musical heritage.

1. BACKGROUND

Groven's background was folk music, and he developed musical skills early in life, particularly on the Hardanger fiddle, a Norwegian folk instrument with four resonating strings in addition to the four strings also found on conventional violins. His experiences with the natural scale from playing the willow flute, and his frustrations when trying to tune a zither to the perfect intervals found in the natural scale, made him aware of the difference between the natural scale and the tempered tuning that is used throughout the Western world. Groven experienced the tempered system as deeply problematic, and found, for example, that the compromises needed for performance in different keys on a piano without retuning for each key change destroyed the purity and clarity of the intervals. He compared the difference between tempered and natural tuning as the difference between looking through a muddy or a clean window. Notably, the natural scale where intervals are described by whole numbers sounds quite different from tempered tuning, where compromises have been made to achieve better playability across the different keys.

Given his background in folk music, Groven knew that the natural scale with variations was the preferred tuning system in Norwegian folk music. Therefore, he viewed this tuning system a necessity in his larger project of bringing folk music into the musical weave of modern Norway, which in the early 1930s was in the process of becoming electrified. With electrification followed the new media technology of radio broadcasting, and bringing folk music into radio programming was important in fulfilling one of broadcasting's promises – increased understanding of national culture and identity, and letting the nation hear itself.

2. EXPOSURE TO TECHNOLOGY

Groven's first treatise [1] from 1927 discussed the natural scale and its predominance in a large sample of Norwegian folk music. His main argument was that the natural scale is a better foundation for deep aesthetic experience than the tempered scale, and that the notation of folk music should be brought back to the original tonality. His demonstrated knowledge about folk music secured him a post in the emerging broadcasting system in Norway, where he from 1931 edited a weekly program about folk music that still exists today. Before recording became possible, the program was broadcasted real-time for several years, and Groven was one of the first to use the portable recording technology purchased by the public broadcaster NRK. First, recordings were made on lacquer disks, then came optical recording, and finally recording used magnetic tape. These recordings would later form the basis for the national archive of folk music. NRK was at the time a hothouse for audio technology, and developed much of the technology we today take for granted, such as for example the sliding fader (1932).

In his task of collecting folk music heritage and bringing it to the general public, Groven depended on the new technologies and was an active proponent of NRK's steady stream of investments. When a new radio building was to be erected in 1938, for example, one of the studios was built with acoustics similar to that of rural log cabins, with the

intention of providing optimal conditions for folk music. He found that when folk music met with the controlled acoustics of the recently invented 'dry' radio studio, the loss of natural acoustics changed the music's character and its bluster was lost. The fact that this consideration was given enough weight to dedicate an entire studio to folk music in an era when modern media technology reigned, says something about the significance of folk music's role at the time. This positive response must have been an important motivator for Groven's development of technologies for just intonation.

3. INTERNATIONAL ORIENTATION

The interest in just intonation and other alternatives to tempered tuning was not limited to Norway, and Groven was familiar with discourse on the topic. In Germany, for example, several researchers were working on the problem of making just intonation available through instrument design. Groven traveled to Germany in 1936, shortly after having constructed a reed organ with 36 keys/octave. In Germany, he encountered systems made by Johannes Kewitsch, Karl Eitz, Federico Busoni, and Puhlmann[1] that used manual switching and/or several or extended keyboards for playing, rendering them unusable for practical use. Groven returned to Norway without a practical solution to the interface-problem. [2] He had nonetheless become familiar with modern oscillographs for measuring frequency accurately, useful tools in his later research.

Notably, well-known early electronic instruments also emerged around this time, such as the Theremin (1919-1928), the Trautonium (1928), the Sphärophon (1921-1926) and the Ondes Martenot (1928). Groven must have been familiar with some of these from presentations that had been made to the Norwegian engineering and arts communities. Maurice Martenot, for example, visited Oslo for the first time in 1928 to present his new instrument. [3]

Moreover, the responses Groven received on his technological inventions and their musical application makes it clear that he maintained contact with a wide group of researchers and musicians, and that he viewed his own work in light of other accomplishments in the field of alternative tuning systems.

4. THE JUST INTONATION INTERFACES

The principle of just intonation is that intervals are described by integer ratios. However, due to the Pythagorean comma, the same pitches cannot be used in all keys. The small compromises in pitch that characterize equal temperament are unacceptable, thus the musician needs have access to a much larger number of pitches to play with just intonation in all keys. There are different opinions on exactly how many pitches are needed, but several researchers, among them Groven, arrived at the conclusion that 36 pitches/octave is sufficient. There are still small inaccuracies with this number of pitches, but they have been found to be below the threshold of perception, and have consequently been ignored. The challenge for Groven was to provide a user interface that was practical for performance of his 36-division.

4.1 Pianos

Groven's first attempt at making a practical instrument was by way of modifying a concert piano, so that levers and electromagnets would retune the piano by changing the tension of the strings to preset values. The selection of key was made with a separate keyboard, and upon selection, the strings would be tightened or loosened. Although the system was realized as proof-of-concept, the solution was plagued by loud creaking noises and electrical problems during retuning, and the piano was not stable. A piano needs time to stabilize after tuning, and the string tension is not at first equally distributed throughout the string- it is only after having been played a bit that the string tension becomes evenly distributed, and the string changes pitch during this process. Given these problems, the piano project was abandoned shortly after having been presented in 1934. However, sketches and written descriptions of another mechanism have been found in Groven's archive material, involving step-motors and pegged rollers, much like those found in music boxes, to adjust the string tension. However, financing attempts failed, and there's no evidence that this piano was ever built.

4.2 Acoustic organs

Groven moved on to the reed organ, and in 1936, a reed organ was built with electrical switching between keys, controlled by a separate manual. The necessary calculations and analyses of the pitch requirements for the different scales had been made [3], and Groven had independently arrived at the same pitch structures Puhlmann had employed as early as 1926. The reed organ was completed just before Groven traveled to Germany to research the status of the field The reed organ was used for several radio broadcasts, but the mechanical switching was impractical – a design flaw Groven also found in one of the German systems.

Groven's solution was to construct a pipe organ with an adaptive automat that would select the correct pitches for just intonation automatically during performance. A musician could then play the organ in a normal manner and not have to deal with several manuals or manual switching during play. The technology was non-invasive, and the musician did not need to change performance practice. The

[1] The organ-builder Puhlmann that Groven refers to is likely to be Wilhelm Puhlmann from Zörbig, who is known to have constructed an organ in Deutsch Bork church in 1910.

tuning of the pipes was the same as in the reed organ, 36 pitches/octave, and the adaptive automat was electronic rather than mechanical, an innovation in itself.

4.3 The adaptive automat

The automat exploited the slight delay in mechanical organs from when a key is pressed until air starts flowing into the pipe. According to Groven, organ keys at the time normally had a free movement of 2-3 mm before activating a pitch, and he designed an electrical contact that would activate a chain of telephone relays immediately after a key was pressed. The relay chain would open for airflow to the correct pipe, and was measured to need at most 62.4 ms to complete pitch selection and rout the airflow. That gave a maximum speed for performances of sixty-fourth notes in the tempo of 60 bpm., and this was fast enough for the organ repertoire.

By choosing key ahead of a performance, one would activate the pitches that were pertinent for that key, however relay chains could be deactivated and activated depending on whether the performed intervals demanded other pitches in order to maintain just intonation. The construction of the relay chains was complex, and the number of relays in the first version of the automat was approximately 300. (Fig. 1) One can compare the construction of the relay chains to programming, and the current version of the logic exists as a Max-patch. The adaptable automat was developed during WWII, and after correcting some mistakes in the programming, a final working version was presented in 1947.

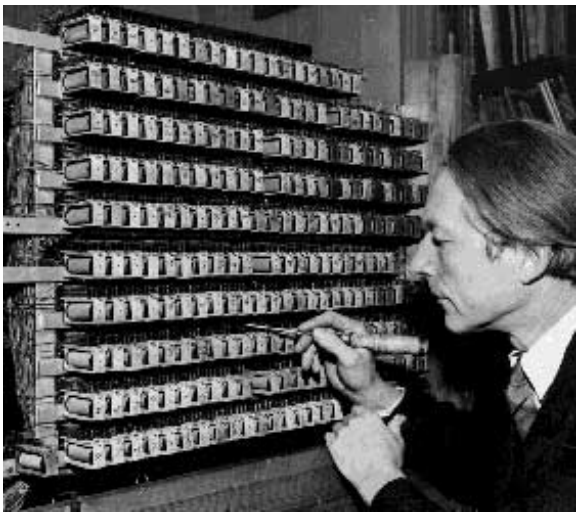

Fig. 1. Groven soldering relays into the first automat.

4.4 The electronic organ

The acoustic organ had only one voice and one manual, and this limitation spurred Groven to construct an electronic organ for just intonation in the early 1950s. The radio engineer and developer Ragnar Bogstad was contacted in 1956, and was engaged to construct an electronic organ. In this organ, Groven wanted to employ a 43-division of the octave, eliminating the small compromises made in the 36-division. More importantly, he wanted to include a number of different and unconventional timbres for his research, including buckhorn pipe, bagpipe, willow flute and jew's harp. This system served as the basis for researching and comparing other tuning systems than just intonation. The electronic organ for just intonation was a unique initiative in the world, and Groven received support from The Research Council of Norway for several years during the 1950-60s to realize the instrument.

The increased number of pitches in the octave, the need for quicker response in the automat due to the increased speed in the electronic instrument, as well as the flexibility needed for working with different tunings, made a new automat a requirement. The Research Council also agreed to fund this development. Bjørn Raad from the Central Institute for Industrial Research planned the architecture, and a new transistor-based automat was built according to these new specifications, including more than 1200 transistors. Interestingly, Groven stated that the electronic organ sounded clearer and better than the acoustic organ, and he saw possibilities in what we today call 'spectral diffusion'. He proposed the use of filters for separation of the harmonics in the organ tones, so that they could be played back through different speakers. The timbral color could then be manipulated after having been produced by the organ, and the sound of for example a bassoon could be taken apart and reconstructed from several speakers in this fashion, partial by partial. However, judging from the loudspeaker cabinet that he built, it is unlikely that his thoughts were as radical as current electroacoustic concert practice, where sounds are distributed spectrally across the performance spaces; his cabinet was approx. 1,5 meters tall and contained several speakers that projected in different directions. An assumption is that he simply might have found that this loudspeaker arrangement would bring the sound projection from the electronic organ closer to that of a pipe organ, better addressing the acoustic space. Nonetheless, his idea of taking musical spectra apart for separate treatment was unknown outside of specialist groups.

Unfortunately, the electric organ ceased to function when Groven returned to the 36-pitch system and connected the transistor automat to the pipe organ, and it has not functioned since. After his death, and during the active management of his legacy, the transistor automat became somewhat unstable, and it became increasingly clear that a migration to digital technology was necessary if the just intonation system were to continue to function.

4.5 Migration and expansion

In 2001, music theorist David Code translated the wiring

diagrams from Groven's adaptive automat to into a Max external object, written in C. [6] An adaption was also made so that the Max-patch sent MIDI-messages on three channels, each controlling a Yamaha MIDI piano. The pianos were tuned to the 36-division of the octave, and the *Groven*

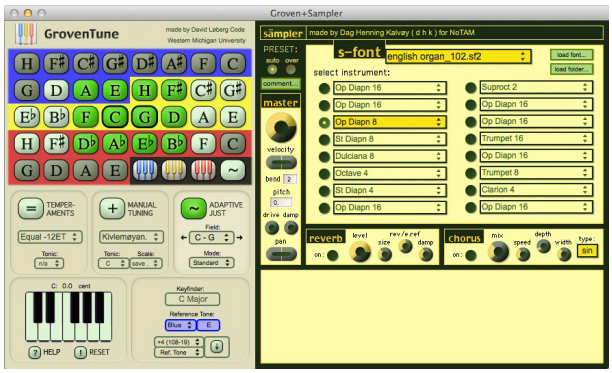

Fig. 2. The Max interface for the adaptive automat and sampler, version 2.0.

piano has since been presented at several concerts. During the same year, Henrik Sundt at NOTAM connected the digital automat to the pipe organ through three MIDI-to-voltage interfaces, and replaced the original automat with a computer and the organ manual with a MIDI keyboard. In 2005, NOTAM in collaboration with Dag Henning Kalvøy made the adaptive automat portable and available for free download together with a sampler and a number of sound fonts. The automat was expanded by adapting a software sampler [8] with microtonal capabilities. The digitization further allowed for mixing the acoustic organ with synthetic sound sources, artificial reverb and other signal processing, picking up on Groven's ideas on spectral manipulation mentioned above. Younger generations of composers show increased interest in these new affordances in combination with conventional instruments, expanding their contact with music technology.

5. SUMMARY

Groven's orientation as a music technologist was international, and the positive response to the sounding results and musical implications of the adjustable automat was significant. [7] He was, however, little impressed by electronic music, and his interest in technology was motivated by the conviction that a much older musical paradigm than national romanticism and/or modernism was important for the development of contemporary music. Groven wanted to make as unabridged use of the musical roots found in nature and local culture as possible, and believed that this was the way for music to touch people deeply.

Groven's project was also relevant for the problematic "national" issue that emerged after WWII, and his focus on folk music was often misunderstood as folklorism, while in effect his position was the opposite – against the urbanized standardization that compliance with the (European) continental tradition entailed. Groven's position was to develop technology in order to maintain and continue to build on original musical roots, making them accessible to new generations of musicians and composers. This is precisely what the migration of the automat to Max, and the development of the portable sampler have accomplished.

Acknowledgments

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