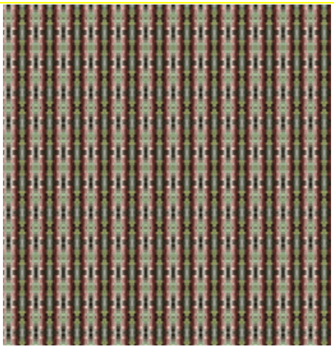

The Piano Automaton as an Instrument for Algorithmic Music (Paper)

Topic: Music

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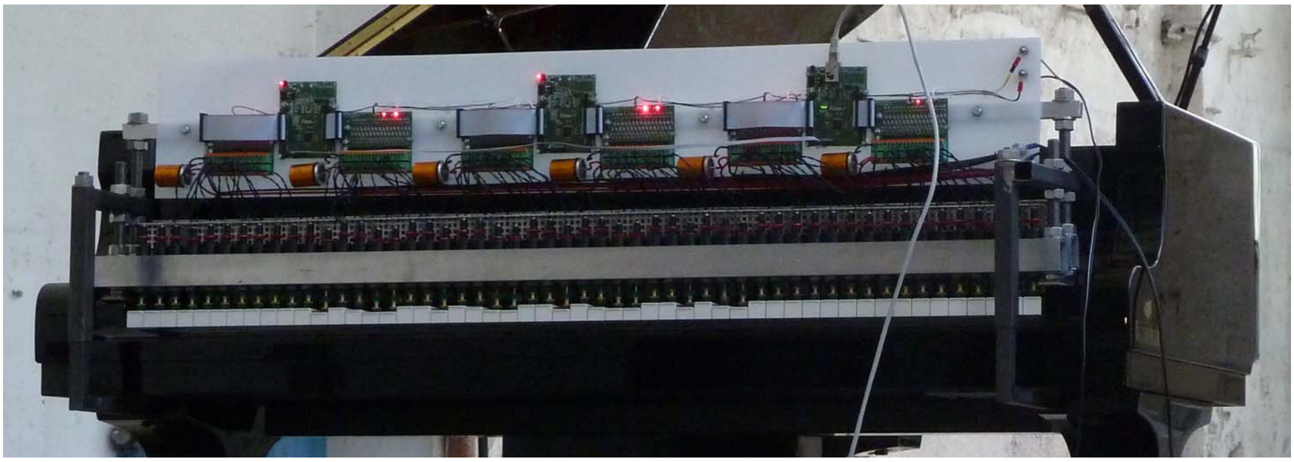
Abstract

The *Piano Automaton* ("Klavierautomat") was conceived and built by the Austrian artist Winfried Ritsch. It is a device to be mounted on any ordinary piano in order to turn it into a computer-controlled instrument.

From an artistic standpoint, several aspects of this system seem interesting. As it connects an acoustic piano to a computer, it is apparently well suited for the performance of computer-generated algorithmic music. Moreover, it allows for several forms of "unhuman" musical expression because the Piano Automaton can not only play faster than a human pianist, it can also play many more keys at the same time – all 88 at once if necessary. And even though the music is computer-generated, there is no electroacoustic sound, but rather the acoustical and physical presence of a real piano.

This paper describes the technical details of the Piano Automaton as well as the compositional concepts of several short generative *Etudes* that have been realised so far.



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Key words: generative music, algorithmic composition, robotic piano player.

Main References:

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The Piano Automaton as an Instrument for Algorithmic Music

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Premise

The piano automaton was conceived and built by the Austrian artist Winfried Ritsch. It is a device to turn an ordinary piano into a computer-controlled instrument. From an artistic standpoint, several aspects of this system seem attractive. As it connects an acoustic piano to a computer, it is apparently well suited for computer-generated music. Moreover, it allows for several forms of 'unhuman' musical expression because it can not only play faster than a human pianist, it can also play many more keys at the same time – all 88 at once if necessary. And even though the music is computer-generated, there is no electroacoustic sound but rather the acoustical and physical presence of a real piano.

1. Introduction

The piano automaton is a device that can be mounted on any ordinary piano in order to turn it into a computer-controlled instrument (see figure 1). This paper describes the piano automaton as well as a few short musical works that were specifically created for it during the summer of 2018. The description begins with an overview of the automaton's background, followed by a report on the author's familiarisation with the characteristics of the automaton. The process of familiarisation turned out to be a method that built a bridge from a more technical to a more musical way of thinking. Eventually, this process led to an artistic result.

A piano automaton is a machine; therefore, it can play music that is beyond the possibilities of a human pianist. Furthermore, it is a computer-controlled device. For that reason, one can argue that the piano automaton is particularly well suited for the performance of computer-generated algorithmic music.

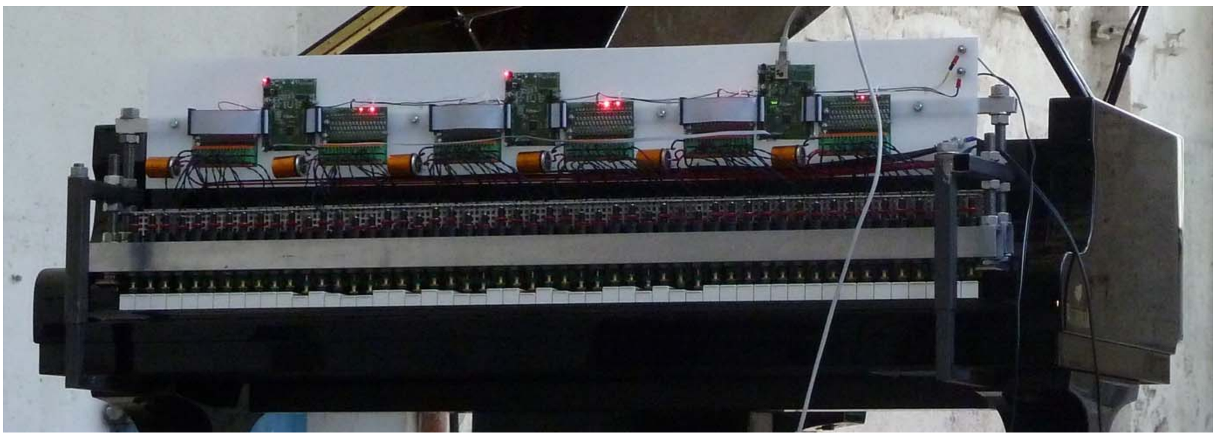

Figure 1. The piano automaton.

2. Background

2.1 History of the piano automaton

The piano automaton was conceived and built by the Austrian artist and researcher Winfried Ritsch in his *Atelier Algorythmics* [1, 2]. Ritsch attempted to realise a specific kind of music that required an instrument with specific features that only a computer-controlled piano could provide. For instance, it was necessary that the piano could play at a very high speed. This required not only sufficiently fast mechanics but also electronic components suitable to facilitate a high data transfer rate. Furthermore, the piano should be able to play and hold down a large number of keys at the same time. Ritsch's research revealed that existing midi pianos (e.g. the Yamaha Disklavier or the Bösendorfer SE) could not completely satisfy these requirements. As it turned out, the main problem was that all these pianos could only play a restricted number of keys at once. This restriction was not surprising considered the fact that these pianos were designed to play classical piano literature. They were not meant to play more notes at a time than a human pianist could strike with his or her ten fingers.

Another criterion that guided the development of the piano automaton was the flexibility of handling. To achieve the desired flexibility, it seemed reasonable not to use a player piano with a built-in playback technology but rather to construct a 'robot piano player', that is, a self-contained device to be put in front of the piano keyboard. This decision was informed by the fact that ordinary pianos are common instruments that are likely to be found in many places, e.g. in music universities or concert halls. Moreover, it is much simpler to transport only a player device than an entire piano. Therefore, Ritsch designed the piano automaton as a player device and attempted to make it easily transportable and readily mountable on any grand or upright piano. After having constructed two prototypes, Ritsch arrived at the final version that he named *Rhea*. Eventually, he built twelve devices of this version one of which has been sold to the Institute of Computer Music and Sound Technology in Zurich in 2018.

Ritsch's piano automaton is closely related to the music of the Austrian composer Peter Ablinger. The realisation of Ablinger's music was, in fact, the main driving force behind the development of the piano automaton. Ablinger explored a musical concept that he named 'phonorealism' (a neologism built in analogy to the word photorealism). With photorealism, the visual arts possess a concept of appropriation of reality. Ablinger tried to achieve an equal phenomenon in music. His work cycle 'Quadraturen' consists of several sound installations and concert pieces that apply techniques similar to those used in the graphic arts to render photographs into prints. To this end, Ablinger makes a frequency analysis of an audio recording and subsequently reduces and quantises the data to make it playable on an acoustic instrument.

One can regard this quantisation of data as a sonic analogue of pixels [3, 4]. Although the frequency analysis data is reduced, it still requires a huge number of notes to approximate the original audio recording. Thus, the computer-controlled piano with its ability to play many notes at a very fast speed is the most suitable instrument for this kind of music.

2.2 Technical details

The piano automaton consists of 88 solenoids to hit the keys of the piano keyboard. These solenoids are attached to a robust metal frame, and their tips are cushioned with felt to avoid unwanted hitting noises. Three microcontroller boards actuate the solenoids. The metal frame is mounted on a piano with two clamps on both sides. The details of the piano automaton are depicted in figure 2.

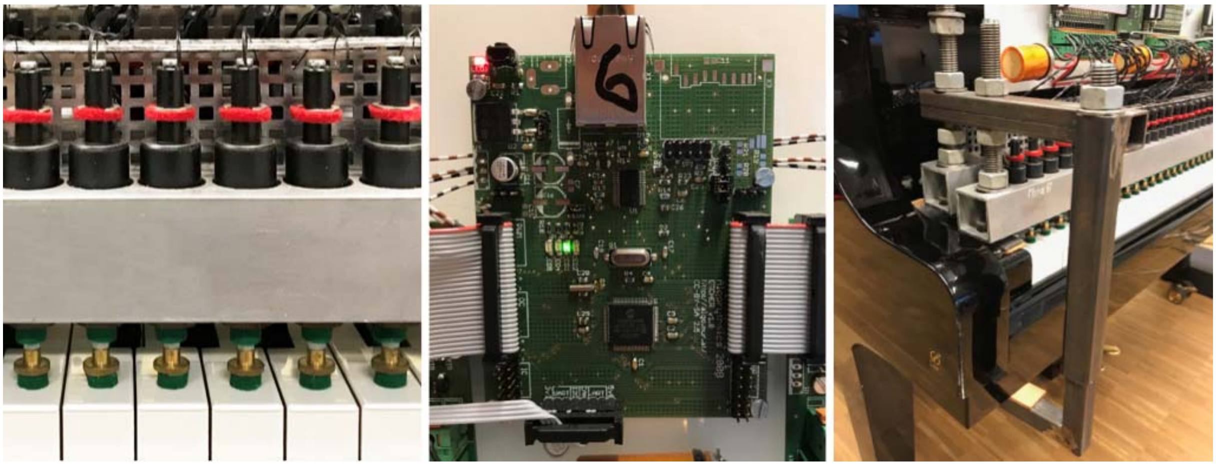

Figure 2. The solenoids, one of three microcontroller boards, one of the clamps to fix the automaton to a piano.

A control software communicates with the piano automaton. This software can receive note-on and note-of commands via the Open Sound Control (OSC) communication protocol. This allows for any OSC-compliant program to run a generative algorithm (see figure 3). Furthermore, the control software can also read and play MIDI-files.

Another important task of the control software is data mapping. For each note, the corresponding solenoid has to be addressed, and the note's velocity has to be scaled to generate the appropriate loudness. As the numbering of the solenoids does not conform to the MIDI key numbers and the transformation of velocity values into a perceived loudness is quite uneven among the solenoids, one must carefully calibrate the automaton before using it. Once this calibration has been executed, its values can be stored in a text file.

Ritsch implemented the original version of the control software in the pure data programming environment. The author has developed a new version in C++ with the JUCE library [5].

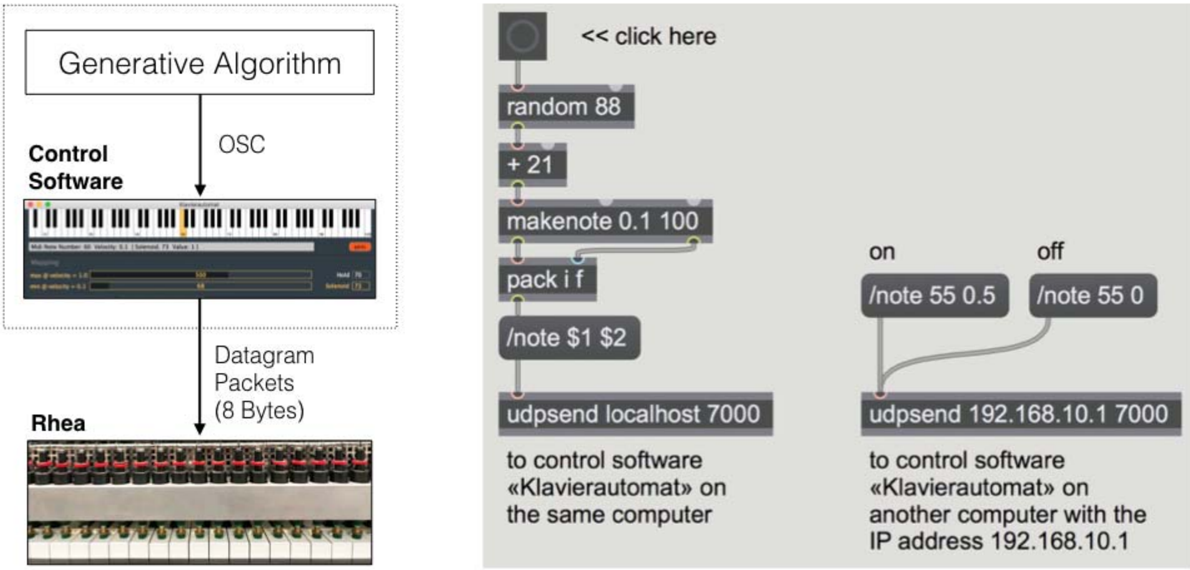

Figure 3. The data flow used for real-time generated algorithmic music (left); an example how to send notes from Max (right).

3. Approaching the Instrument

Once the piano automaton had been delivered to Zurich, the author spent several weeks familiarising himself with the characteristics of this device. Apart from learning how to fix the automaton on top of a piano, it was most important to find out efficient strategies to calibrate it. The calibration procedure turned out to be quite intricate as there are several, interdependent parameters that influence how loud a note is perceived. These parameters include not only the velocity of the solenoid but also the duration of the note, the height at which the key is to be held down by the solenoid and several mechanical conditions such as the position of the automaton relative to the piano keyboard. Due to the interdependence of these parameters, it was only possible to arrive at an even loudness over the whole range of the piano by finding reasonable compromises. The calibration procedure was considerably facilitated by equipping the control software with a helper function that repeatedly plays keys at various velocities.

To further explore the automaton, several tests were carried out to find out about the maximum speed at which a key could be repeated, about the maximum loudness that could be achieved and so forth. This process of approaching the automaton turned out to be very important to eradicate some incorrect assumptions about the precision and the uniformness of the automaton's playback.

As the process advanced, the focus gradually shifted from technology to music. Originally, the only purpose of the test series was to explore the physical limits of the automaton. After a while, these tests became gradually more playful and more informed by musical criteria. It seemed to be important not only to fathom out the technical possibilities of the automaton but also to find the artistic potential within these possibilities. Finally, it was a small and logical step to proceed from these test series to artistic studies.

The author eventually realised six short pieces entitled *Etüden für Klavierautomat* ("etudes for piano automaton"). These pieces do not deny that they stem from test series. They are all quite short (1.5–2 minutes) and concentrate on one single idea which can be either a technical aspect, a (psycho-)acoustic phenomenon or a musical concept. The following sections describe these etudes in detail.

4. Works

4.1 Etüde #1 ("Moiré")

This etude is about the temporal precision that can be achieved with a computer-controlled piano. The music consists of 14 different superimposed tempos. The pitches E and *F* in all octaves are repeated at different speeds (see figure 4). The inter-onset intervals of these repetitions are 198 ms, 199 ms, 200 ms and so on up to 211 ms. The result is a slowly changing musical texture in which several moiré patterns appear.

As this music is harmonically very reduced, it directs the listeners' attention to the temporal phenomena. In its superimposition of several only slightly diverging tempos, this etude relates to the concept of 'phasing' in minimal music.

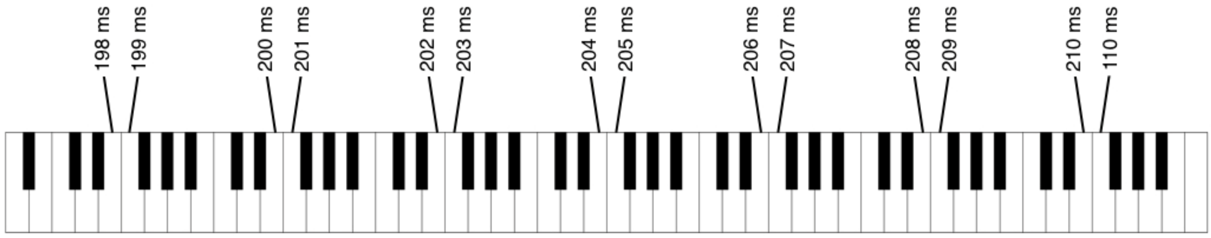

Figure 4. The inter-onset intervals at which the pitches are repeated in Etüde #1.

4.2 Etüde #2 ("Scales")

This etude explores the effect of harmonic colour in monophonic music. It consists of scales played downwards across the whole keyboard. The speed at which these scales are performed slowly oscillates between 20 and 200 notes per second. Even though there is always only one note simultaneously played, the music creates a notion of harmony. This is particularly due to the fact that these notes are played in a fast tempo.

The choice of pitches in this etude is constructed as follows. The 88 keys of the piano are subdivided into four groups of 22 keys. A pattern of ten intervals is randomly generated and applied to each of these groups (see figure 5). The notes thus obtained are played in a swift movement from the top note downwards. Upon reaching the lowest note, a new interval pattern is generated, and the next descending movement starts. Another process, which spans over the whole piece, is a slow but continuous decrement of the size of these patterns. As a result, the descending movements become more and more sparse and perforated. The change of pattern induces a variation of the harmonic colouration of the music.

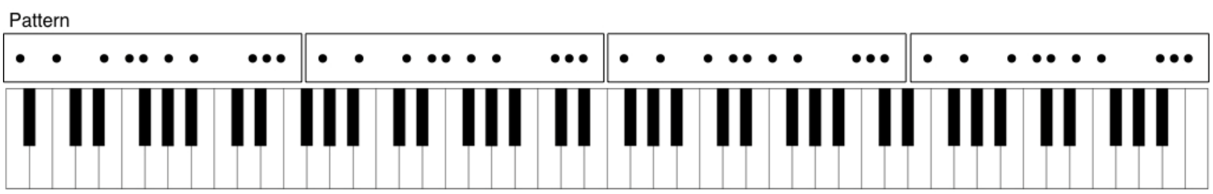

Figure 5. The same pattern is applied four times to construct the harmonic structure of Etüde #2.

The way in which these patterns lead to a harmonic colouration somehow relates to tonal music. In our tonal system, all pitches can be subdivided into groups of twelve chromatic steps because the perceived quality of pitch repeats every octave (a concept known as ‘pitch class’). Every scale or mode, apart from the chromatic scale, can be understood as a pattern applied to these groups. A diatonic scale, for instance, is a specific choice of seven pitches out of twelve. Depending on the structure of this pattern, we can determine the mode of that diatonic scale (major, minor, etc.) and consequently hear a specific harmonic quality.

4.3 Etüde #3 (“Shadow Harmony”)

The basic idea of this etude is auditory masking, i.e. the effect of a louder acoustic signal covering a quieter one. Throughout the piece, there are always two chords played at the same time; one is very short and loud, the other one quiet. An interesting sound effect results from the loud chord masking the attack of the quiet one. The timbre of the piano is characterised by its attack and its percussive quality. As the quieter of these chords seemingly lack an attack, it gets an unreal, shadowy quality as if these notes would appear from nothing.

All the chords are randomly generated. Their harmonic quality, however, changes back and forth between two types. These changes always take place after approximately 15 chords have been played. The masked chord is atonal for the first type of harmonic quality and tonal (i.e. a minor triad) for the second type. The masking chord, however, is always atonal.

4.4 Etüde #4 (“Glissandi”)

This etude is about the rapidity of the piano automaton. At a speed of 200 notes a second, chromatic scales are played up and down. The keys are hit so quickly that some of them almost do not speak, which lends the music a volatile and hasty character. The generative process for this etude operates on two temporal levels. On the first level, it produces a chromatic scale that runs up and down between a lower and an upper boundary. Whenever the scale hits a boundary, the movement is mirrored, and the chromatic scale runs in the opposite direction until it reaches the other boundary, and so on. On the second level, the generative process sets the two boundaries to new random pitches about twice a second (see figure 6). The ever-changing boundaries lead to a constant metamorphosis of the glissando gestures.

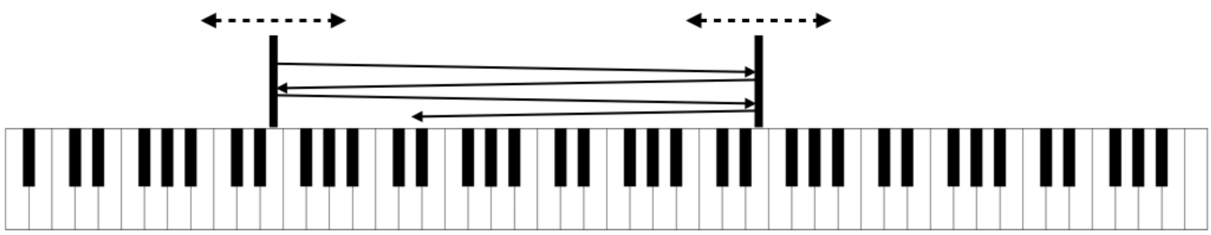

Figure 6. Rapid chromatic scales are played up and down between two moving boundaries in Etüde #4.

4.5 Etüde #5 ("Stairs")

Shepard tones inspired the fifth etude. This auditory illusion, named after the cognitive scientist Roger Shepard, creates the effect of a tone that endlessly ascends or descends in pitch. If a Shepard tone, for instance, ascends one octave, which is unambiguously perceivable as an upward movement, it paradoxically arrives at the same pitch as where it started. Usually, Shepard tones are electro-acoustically created; here, this illusion has been as close as possible approximated on the acoustic piano. Every pitch is doubled in all octaves over the whole range of the piano. The loudness is at its maximum for the note in the middle octave and decreases towards both sides (see figure 7).

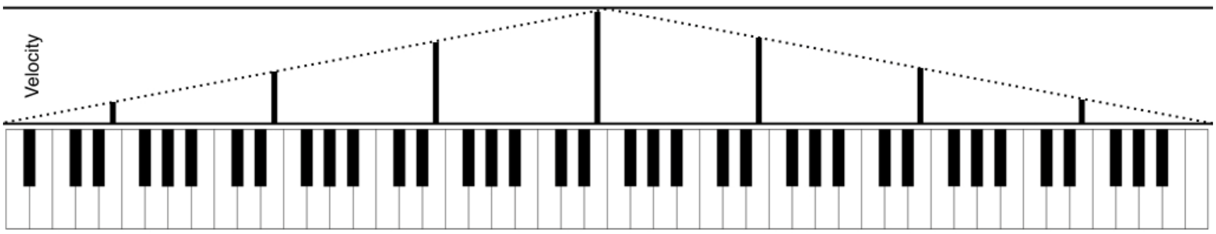

Figure 7. The distribution of velocities among the parallel octaves

At the beginning of this etude, an ascending chromatic scale is played. After a while, this regular movement becomes increasingly distorted. More precisely, all melodic intervals are initially ascending minor seconds. Over the course of the piece, the probability for larger intervals rises, that is, the occurrence of ascending major seconds, minor thirds, major thirds and so on becomes gradually more likely. The increased probability for larger intervals leads to the emergence of manifold melodic patterns.

4.6 Etüde #6 ("Repetitions")

This etude is about sound masses. A generative algorithm randomly chooses pitches. For each chosen pitch, it starts a process that repeats this pitch 120 times at a randomly chosen, but steady rate. During this repetition, the velocity of the keystrokes gradually raises from very soft up to maximum force. Of course, the duration of this process varies due to the diversity of the randomly chosen rates.

Several of these processes run concurrently. Over the course of the piece, the time to wait until a new pitch is chosen and a new process is started gradually becomes shorter. As a result, the sound becomes increasingly more massive, and the large number of simultaneous pitches generates different sound colours, which is an effect vaguely resembling additive synthesis. Moreover, several rhythmic textures emerge due to the different superimposed tempos.

5. Conclusion

The piano automaton possesses several characteristics that make it a most suitable instrument for generative music as exemplified by the six etudes described in this paper. First of all, it is a computer-controlled device; hence, playing computer-generated algorithmic music is an obvious thing to do. In addition, the piano automaton allows for 'machine music', that is, it facilitates a kind of musical expression that no human pianist could possibly master. The machine music properties can be assigned to the six etudes as follows:

- speed: especially Etüde #4, but also Etüde #1 and Etüde #2.
- loudness, massiveness: Etüde #6
- precision of time: Etüde #1 and Etüde #3
- precision of loudness: Etüde #3 and Etüde #5

Two of these properties, speed and massiveness, are always connected with a large number of notes. Generative algorithms are a convenient means to control them. For instance, the composer specifies a meta-process and leaves the details to the algorithm, e.g. a random generator.

Composers might be attracted by the piano automaton because it enables to realise computer music on an acoustic instrument. As every mechanical instrument, the piano automaton possesses certain physical limitations and irregularities. The choice of instruments always confronts the composer with certain restrictions and idiosyncrasies. Very often, working around and against such limitations can stimulate the creative process as these restrictions pose problems that the composer has to solve. In this respect, they become a driving force for the creative process.

This applies in a similar vein to the process of getting acquainted with the piano automaton. The exploration of the automaton's characteristics provided the basis for subsequent artistic work as it gave the impetus for further musical and compositional thinking.

Last but not least, a 'non-musical' quality of the piano automaton must be mentioned as well: The appearance and the physical presence of the piano automaton holds a strong artistical attraction. The visibility of the circuit boards and all the other mechanical and electrical components lends the device a very technical look which stands in stark contrasts with the traditional aura of the piano.

6. Outlook

To further explore the piano automaton, the author, as well as other composers, will try to realise longer pieces. In contrast to the short etudes described in this paper, those works will not only be much richer in details but also built on a real musical narrative as opposed to just one single idea. It seems also worthwhile to explore other scenarios such as a combination of the piano automaton with acoustic instruments played by human beings in a chamber-music setting or to control the piano automaton in real-time with different kinds of sensors in an interactive improvisation setting.

Several technical developments are planned as well. The firmware of the microcontrollers needs reprogramming to allow for even more subtle dynamics, and especially the possibility to silently depress and hold keys. Furthermore, some parts of the hardware need improvement as well. The springs that pull back the solenoids are quite prone to breaking, hence, they have to be remade in a different material or shape. Finally, it is planned to build a 'pedal automaton', a companion device to operate the pedals of the piano. Having such a device would be most desirable for many composers.

7. References

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