Performing the Electric Violin in a Sonic Space

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How can a performer use the body to control live electronics? This is probably one of the most discussed and explored topics in the world of computer music performance. Our approach to the topic has been through reduction and simplification of the technological setup, something that has resulted in the feeling of greater artistic and expressive freedom.

The starting point for the work being presented here was the idea of letting the performer (the second author) “navigate“ in a large soundscape on stage. As an electric violinist she has been playing with electronics for a long time, enjoying the possibilities of wireless audio transmission and not having to worry about sound feedback. However, as she started to explore various types of sound effects and processing, the growing collection of effects pedals, MIDI controllers and computers led to the need for cables and a physical (and visual) presence of various technologies in performance. The aim of this project was to explore how she could liberate herself from the technology (and cables) and move freely in space again.

The result of the project, the piece Transformation, was conceived of as contrasting the other pieces that the performer has developed over the last years, all of which are sonically dense and with a lot of visual information. We therefore wanted to create a minimalist piece with sparse use of electronics, with little visual clutter, and that allowed the performer to improvise freely with the electronics while controlling everything herself.

From our initial discussions, several research questions appeared: a) How can we create an ‘invisible‘ technological setup, that still allows for a fine control of the live electronics? b) How can we create an electronic part that allows for interaction
possibilities that are musically interesting for the performer? c) What type of sound processing/creation can be used so that the performer feels in control of the whole sound palette during performance?

Our main aim in this paper is to give a thorough explanation and evaluation of the artistic research and development project we have undertaken. Through the critical reflection and discussion of our own practice, we also hope to contribute to the growing literature of artistic practice in general. But first we will start by presenting some background information on the technological challenges that the performer has explored over the years, and our solution to overcome some of these challenges.

**Background**

The starting point for our collaboration was the performer’s wish to be liberated from a technological setup that forced her to be stationary during performance. Being a classical violinist by training and profession, she has turned to performing mainly with electric violin over the last 10 years. This transition was based on wanting to explore a larger sonic palette (and other musical genres) than is possible with an acoustic violin. The electric violin opens for a feedback-free starting point for sonic explorations of various types of live electronics. There are many different types of electric violins: MIDI violins, multi-pickup violins, etc. In this project we have been using a traditional 4 string electric violin with a standard mensur length, and a regular built-in pickup.

The performer’s main focus has been on exploring a large set of extended performance techniques on the electric violin over the years, many of which are explained in (Strange and Strange 2001). It is interesting to note here that many of the well known extended techniques that have been developed for the acoustic violin may be extended further when performed on an electric violin and combined
with live electronics. Examples of such techniques may include bowing on the
tailpiece, pegs, and body of the instrument, which, combined with distortion effects
or strong reverberation, open new and exciting soundscapes. Other techniques
include the use of crush-tones, using metal parts on the bow to produce sound, or
bowing directly on the bridge or behind the bridge works well with delay and with
granulation.

The performer has explored several different strategies for controlling live
electronics: a) effect and sampling pedals, b) MIDI foot controllers, c) machine
listening systems, d) instruments with attached sensors, e) hyperinstruments, f)
hand/bow-based controllers, g) motion capture. All of these techniques have some
benefits and challenges, which we will discuss in the following sections.

**Performing with effects pedals and foot controllers**

There are many positive aspects of using guitar pedals with electric violin: they are
easily available and easy to use, have standardized settings and a long tradition in
the guitar world. With the right combination of pedals, it is possible to explore a
large sound palette, and hence also many different musical genres.

Some performers, including Kimura (2003), have argued that using pedals may
have an impact on the violin technique and may be distracting for the audience.
This, however, depends entirely on how the pedals are used and how seamlessly the
use of the pedals are integrated with the rest of the performance. After ten years of
performing both composed and improvised music with various types of pedals, the
performer feels that the pedals have become an integrated part of her extended
instrument. They require no extra cognitive load during performance, and integrate
well with the various pieces she has developed. Another important aspect of
performing with pedals, as opposed to other types of controllers, is that they free up
the hands to carry out regular violin performance actions.
There are, however, some challenges when performing with pedals. For example, some pedals give a clicking sound when changing settings, which is often a much larger distraction than the visual effect of pressing the pedal. Second, having a large set of pedals calls for a cluttered and complex setup. Third, most pedals are based on effects *processing*, i.e. they are sound-modifying and not sound-producing.

Some of the drawbacks of effects pedals may be overcome by using (MIDI) foot controllers connected to a hardware sampler/synthesizer or computer. While the technical possibilities are larger with such controllers, the performer’s experience is that such a setup may actually be more restrictive than using separate pedals. First, even though the controller part of the setup uses less space, and requires less cabling than having a number of individual pedals, the addition of a computer makes the setup more complex. Second, while having the possibility of controlling e.g. two-dimensional effects with two different foot pedals, this is only possible when sitting down. As such, the physical performance space is considerably reduced. For this reason we decided to explore other types of controlling the electronics on stage.

**Performing with hand-based controllers**

There have been several research projects that have focused on bow-based violin control over the last decade: *Bossa* (Trueman and Cook, 2000), *Hyperbow* (Young, 2002), the IRCAM bow (Bevilacqua et al., 2006), the NOTAM bow (Guettler et al., 2008; Wilmers, 2009), and the commercially available K-bow (McMillen, 2008). A different yet similar approach is to place the sensors on the hand instead, as done in the *Overtone violin* (Overholt, 2005). While there are certainly many interesting aspects of performing with such sensors, our experience with two of them (NOTAM-bow and K-bow) have also shown some problematic sides that we will discuss in the following paragraphs.
Construction: We find it problematic that the electronics add some mass to the bow and changes the tipping point. Quantitatively these changes are not very large, but for a highly skilled performer it is noticeable and it requires adjustment while playing. Adjusting the technique for a specific bow is possible, but not ideal if changing between bows in performance. Also, adding fragile electronics to the bow reduces the performance possibilities of the performer.

Technology: We have experienced that the wireless communication in these devices (and others) is not (yet) solid enough for being truly reliable in performance. Bluetooth connections have proven to be notoriously unreliable, particularly in large concert halls. For this reason we are currently exploring ZigBee communication and various constellations of sensor networks (Torresen et al., 2010), which seem to overcome some of the problems.

Interpretation: Even with stable wireless communication, interpreting and mapping data from inertial sensors is not a straightforward process. For example, while accelerometer data give seemingly useful information, they only indirectly represent physical acceleration. Second, finding absolute position based on inertial sensors is not a straightforward process, and even the most advanced commercial systems experience considerable amounts of drift (Skogstad and Nymoen, 2011). Thus, thorough calibration (and re-calibration) is necessary to ensure a stable system in performance.

Concept: While it is certainly fascinating to track motion/position of the bow, we are not convinced that it is artistically interesting. For a violinist the bowing is already the most expressive part of her regular performance technique. Having to use the bow for also controlling the electronics means that less focus will put on using the bow for playing the violin. Even when using seemingly “transparent,” machine learning techniques (e.g. the Gesture Follower (Bevilacqua et al., 2007)), our
experience is that the performer starts using the bow differently when she knows it is being used for parameter control.

**Machine listening systems**

As argued by Kimura (2003) realtime sound analysis may be a better way to capture information about the performance than tracking using a sensor bow. We have tested some different types of machine listening systems, primarily based on tracking pitch (using fiddle~ (Puckette et al., 1998)) and some basic spectral features (using analyzer~ (Jehan, 2005)). The positive side of such a system is that it allows for touchless control of the system. The downside is the precision of the tracking and the fact that you need to produce sound to get anything to track. When developing an electronic part we are often thinking about how the electronics can contrast the acoustic/electroacoustic sound material coming from the instrument. We therefore wanted to control sound also when not playing, and this effectively rules out machine listening as control method.

**Motion capture**

Motion capture technologies are increasingly becoming popular in various types of interactive systems. While motion capture may be defined as any type of system that can track any information about a person’s position and motion in space over time, we will here use it to denote systems that can track full-body motion.

We have tested several different full-body motion capture systems to see if they could be useful for our project. Using an infrared optical motion capture system (Qualisys or Optitrack) was abandoned early in the process. Such systems provide for accurate, precise and fast tracking of absolute position, but they are not an option for a performing musician. Even though there exist affordable systems these days (e.g. Optitrack), the large amount of equipment needed (cameras, stands, cables),
calibration challenges, etc., makes it too complex to tour with for a single musician. Then an inertial-based motion capture system would be a better solution. Here we have tested the Xsens MVN motion capture suit, a commercially available system that can capture absolute position based on inertial sensor fusion (accelerometers, gyroscopes and magnetometers). This is a fully integrated on-body system which is transportable in a medium-sized suitcase, and which provides high speed, accuracy and precision, as well as wireless connectivity. As such, it solves many of the problems that are found with optical infrared systems, but it creates others. We have experienced problems when it comes to wireless communication stability and drift of absolute position. The biggest problem with such a suit, however, is that the suit itself is quite heavy and uncomfortable to wear. Also, the visual presence of the suit makes the technology very present, even if trying to hide it under regular clothing.

The conclusion from our testing of various motion capture solutions was that this was not along the artistic lines that we were interested in pursuing: minimalism in both music and technology. This led us to test *video analysis* as a motion capture technique. Video analysis is comparably slower and less precise than all the sensing systems presented above. The big advantage with video analysis, however, is that it can be entirely unobtrusive for the performer. Also, video analysis can easily be used to track absolute position in space.

The perhaps biggest challenge when working with video analysis in a performance context is the separation between foreground and background. This is particularly problematic when moving between different concert venues: large and small rooms, different lighting conditions, etc. Our solution has been to place the camera in the ceiling and use a greyscale image as the source material for the analysis. As will be discussed in the next section, such a setup has met our requirements of being easy to set up and having no cables on the body of the performer.
Setup

Figure 1 presents an overview of the technological setup we have developed for *Transformation*. It is based on a pre-recorded and pre-analyzed database of sounds, realtime video analysis, position to sound mapping, and sound spatialisation. The following sections will describe the three main parts of the setup: motion capture, sound synthesis and sound spatialisation.

Figure 1: An overview of the developed system (boxes with dotted lines show the non-realtime parts).

Motion capture

For the video tracking we have used some of the video analysis modules implemented in the Musical Gestures Toolbox (Jensenius et al., 2005) for the open framework Jamoma for Max (Place and Lossius, 2006). Figure 2 shows a screenshot from the Max patch, where three different modules are used for getting video from the camera, calculating the *motion image* (the running frame difference), and using this as the basis for finding the area and center position of the motion image. Then we know the location of the performer in space, and how much she moved.
Figure 2: Screenshot of the Jamoma video analysis modules in Max. The input module reads video from the camera, and passes on to the motion module that calculates the motion image. Finally the box module calculates the area and center of motion, the latter visualized as a circle on the head of the performer.

In our current setup we have decided on a minimalist tracking system where only two parameters are output: the horizontal (X) and vertical (Y) components of the centroid of motion. This can be seen as a very limited set of control parameters, but has in fact proved to be very useful in performance.

The first author has been using these video modules for analysis and performance for many years, and they have proven to be very stable and reliable in all sorts of conditions. The advantage of using this approach is that it is CPU friendly compared to many other video tracking methods, and no calibration is needed other than simple threshold adjustments. This makes it possible to comfortably run the video analysis alongside sound processing on a normal laptop.

**Sound synthesis**

For the sound synthesis part we tested several different types of sound generation engines. Purely synthetic approaches were abandoned early on in the process, since we wanted to work with recorded sound material from the violin. The question, then, was how we could work with playing back recorded sounds in a physical space.
Our first experimentation was based on distributing the sound files linearly in space, so that the performer could “scrub” through the sounds when moving on stage, similar to what has been explored in the *Embodied Generative Music* project (Peters, 2010a). The intuitive connection between location on the floor and the sound being played back gave the performer a sense of being in direct control of the sound by merely walking through the room, and she would also start to remember exactly where the different sonic objects were located.

But the setup was also limiting and did not feel enough like an instrument to the performer. First, the spatial and temporal resolution of the video tracking (640x480 pixels at 25 fps) was not sufficient to give the performer a sense of fidelity in the interaction with the sonic space. Second, the interaction felt to linear, since she could only scrub through the files in one dimension (back and forth). Third, we did not find a good solution for turning sound playback on and off when she was moving in and out of the captured space. All in all, we found that the ‘stripes’ was not the best solution for what we wanted to achieve musically, so we abandoned the idea and moved on.

The second sound synthesis method we explored was *concatenative synthesis*, using the CataRT library (Schwarz et al., 2006) and FTM (Schnell et al., 2005) for Max. This method is based on cutting up a collection of sound material into small sonic fragments, each of which are analyzed using a set of low level audio features: pitch, loudness, periodicity, spectral flatness, etc. The final result is a database containing pointers to each of the original sound files, the start and stop position of each segment, and the results for all the extracted features. These features are then used for plotting the relative distance between the sound fragments in a 2-dimensional display.

We immediately discovered that mapping the 2D position in space to the 2D control space of CataRT was very intuitive for the performer to work with. Also,
since sounds in CataRT are grouped according to sonic qualities, it is possible to import a large set of sound files and have CataRT group similarly sounding sound fragments close to each other. This makes for a very rich and nuanced sonic space that is interesting to play with.

After experimentation with different types of sound material, we have come up with a sample library of approximately 10 minutes of different violin sounds (mainly pizzicato and flageolets), which is used as input to the system. In CataRT we are using a window size of 250ms, a duration which is perceptually relevant but still short enough for being able to be spliced with other sounds. We have found that a sonic distribution with spectral centroid on one axis, and periodicity loudness on the other is the most interesting combination for interacting with our sound database. This setting gives the performer (and the audience) a clear perceptual understanding of the two axes, while still allowing for interesting sounds to appear close to each other on the floor. We prefer the ‘fence’ triggering method, since this makes it possible to only trigger sound objects when you are close to them, but there will be no retriggering if you are standing still between groups of sonic objects.

**Speaker setup and sound spatialisation**

The last part of our system is the *spatialisation* of sounds in space. Since the piece is focusing on exploring the physical space through a virtual space, we also wanted to distribute sound in space dependent on where the performer was moving.

For the last performances of *Transformation*, the room has been set up with chairs on all four sides of the stage, a set of smaller speakers at the corners of the stage area, and four larger speakers on the diagonals close to the walls (see Figure [Error! Reference source not found.]). Then a simple one-to-one mapping was set up between location on the floor and the placement of sounds, so that the sound would move around the space with the performer. This was achieved using *vector based*
amplitude panning (VBAP) (Pulkki, 2001), a CPU efficient sound spatialisation technique.

Since there is no (audible) acoustic sound from the electric violin, we have explored different solutions for projecting the violin sound in performance: through all speakers, through a single, separate speaker or spatialised with the sounds from the computer. We have found that the latter has been the most successful, since it makes the connection between physical location of the instrument and actual sounding result more obvious.

Even though all performances of the piece have been carried out in fairly reverberant spaces, we have still found the need to add a little extra reverb to the sounds being played from CataRT. The concatenative synthesis cuts the grains accurately, and even though there are no clicking or glitches in the playback, we have seen the need for some additional reverb to create a more holistic soundscape.

The piece
The piece Transformation is the result of an artistic development process where we have explored a cycle between development of the technologies, recording and selection of sonic material, exploration in workshops, public performances and critical reflection of the process. The piece may be seen as what Dean (2003, p.xiii) calls a referent-based improvisation. A framework has been developed, which consists of the sonic space mapped onto the physical space we work in. This is then used to plan a route that the performer will move through around the space. Although this path is planned, the piece is highly reliant on the interplay between the performer and the sounds coming from the computer.

Performances
The piece has so far presented in four public performances (see video excerpts on the DVD). The first of these were in the foyer of the Norwegian Opera & Ballet on 26 November 2009. Here we performed as part of a larger setup, and with sonic material from bells and water drops. The setup consisted of 5 speakers aligned in a row against the ceiling, and both authors participated in the sonic exploration of the space in performance. Still in an early stage of development, this performance reassured us that the setup worked properly, was easy to set up, was intuitive to play with for the performers, and that the end result was perceivable by the audience.

The second public performance with the setup was at the National library of Norway on 4 February 2010, this time with 8 speakers in a row at the front of a small stage (Figure 3). Due to constraints of the performance space (too narrow), the interaction with the space became mainly one-dimensional. On the positive side, this was the first performance with a new set of violin-only sounds.

The third performance was at the Norwegian Academy of Music on 3 September 2010. Here we set up two squares of speakers, one set of smaller speakers at each of the corners of the defined stage area. These speakers were facing inwards so that the performer could hear the sounds, but also because we wanted to make the audience experience the sounds as coming from “within” the space. Four larger speakers were placed at the outer corners of the room, and were used mainly to add a little low-frequency content to the sound mix.
Figure 3: Rehearsing before the performance at the National library of Norway (4.2.2010). The 8 speakers can be seen lined up at the front of the stage, and a small sub was placed on the left side.

Figure 4: Rehearsal before the performance at Norwegian Academy of Music. Parts of the computer and mixer setup to the left, the camera hangs in the ceiling, and the 8 loudspeakers are placed in two squares around the quadratic stage area.

A picture from the performance can be seen in Figure 5. Here a white dance carpet and white lighting was used to create a visual “emptiness” in the physical space, and thereby enhance the presence of the sounds in space. This was the first performance where we felt that we got closer to what we were originally looking for. However, since the setup worked so well it became apparent that the sound material could be improved.
Figure 5: An image from the concert 3 September 2010. A visual element, the white carpet also marked the boundaries for the video analysis area.

Before the fourth performance, on 28 March 2011 at the Norwegian Academy of Music, we recorded a new set of sounds, and with better sound quality. Here we mainly focused on subtle, sustained sounds: flageolets and various types of bowing on the bridge and on the body of the instrument. The performance setup was quite similar to the third performance, but one important change: this time the white dance carpet was placed on a 50cm high stage platform. This made the white square stand out much more clearly in space, and it also lifted the performer so that the audience could see her more clearly.

Figure 9: From the concert 28 March 2011. Here the stage was lifted so that the white square became more visible.
Discussion

This section will start by an evaluation of the setup, interaction and artistic results. This is followed by a reflection on some topics that have emerged from the exploration. Finally, we conclude with some directions for future research.

Evaluation

The current exploration has been carried out employing an artistic working method, an iterative process following a systematic “trial and error” approach. The process has been subject to a critical evaluation after each workshop and performance, focusing on three levels: technology, interaction and sonic output.

Technology

The evaluation of the technological setup can be summarized in these points:

**Rigging:** We have created a setup that could be taken on tour, and therefore should be easy to rig up and down. For our current solution, the most time-consuming part is to mount the camera in the ceiling. With a ladder or stage lift available the entire system can be up and running in less than 15 minutes (not taking speakers into account).

**Stability:** The software system uses three core components: Jamoma, CataRT and VBAP for Max. All of these have been extensively tested and used in performances by a number of people for many years. We have not experienced any instability issues in workshops or performances.

**Usability:** The software has been developed so that the performer should be able to run the performance by herself. When the system is turned on it does not require any attention or control besides general sound level adjustments by a sound technician.
**Scale:** The setup scales well to different physical spaces. The main limitation is the height of the ceiling, but this can be adjusted with changing the camera lens. The audio setup also scales well, and we have been testing different types of speaker constellations in performance: 5 speakers in a row, 8 speakers in a row, and 4+4 speakers in two squares. As such, the technical setup and conceptual ideas can easily be adjusted and scaled to different venues and settings.

**Interaction**

The possibilities of interaction can be seen as a combination of technological and artistic elements:

**Freedom:** The setup has given the performer freedom to do what she wanted musically. She could interact with the electronics and with the whole sound palette available, and also actively work with silence.

**Complexity:** A core challenge when developing the system was to create a setup that was complex enough to be performed with for longer periods of time. Our initial testing with laying out sound files in space did not have the complexity we were looking for. One main reason for this was that the resolution of the tracking was too low; hence the mapping to sound did not give the level of detail that would have been necessary. When using CataRT as a sound engine, with a distribution of hundreds of short sound fragments, we find that there is a good balance between complexity and simplicity.

**Creativity:** The system has proven to be very inspiring to work with, since it has liberated the performer from standing/sitting still with various types of electronic devices. The fact that she can now move freely, and generate sound through her movements and position in space have opened for a different approach to improvising with her instrument and with the computer. Also, the fact that the system will pick short sound fragments from a large collection makes it impossible
to predict exactly what type of sound material will appear. This element of surprise, but within some limitations, is highly valued by the performer, since it gives her freedom to improvise with the system.

**Reproducibility:** At the same time as it is important to have a system that is creative and complex, it is also important to know how it will respond (Kimura, 2003). In that sense, CataRT’s distribution of sounds based on perceptual features has proven to be of vital importance. The performer knows where different sonic qualities can be found on the floor, and this allows her to move back and forth and (re)discover various sound objects.

**Dimensionality:** The current tracking solution is very simple as it is based on only 2 parameters: XY position on the floor. As discussed in section 2, we have tested a number of other types of control systems, all of which output more control parameters. However, our experience is that the current reduced model works better for us, since it allows for simpler setup and more intuitive interaction. Our testing of 3D/6D sensors and devices did not yield more interaction, rather the opposite. The performer is already spending most of her focus on playing the violin, and has limited cognitive bandwidth available for controlling the computer. Having to work in more dimensions would interfere with the sound-producing actions on the violin. As such, moving in a 2D space has made it possible for her to continue performing with her traditional violin technique, while still being able to control the electronics simply by moving on the floor.

**Playability:** In *Transformation* we use pre-recorded sound material, and the musical interaction with the electronic part is based entirely on the performer’s position and motion on stage. There are no pre-determined musical structures in the sound synthesis. As such, the system more resembles an instrument than a pre-composed music machine. This is one of the things we like the most about the system, that it allows to be played with for extended periods of time.
Sonic/musical output

The sonic output is based on the merging of the direct sound from the electric violin and the violin sounds coming from the system.

**Violin:** Our experimentation, and also that of others (e.g. as reported by Palacio-Quintin, 2008), has shown that sensors/controllers may greatly interfere with the violin technique. Our current system allows the performer to play her regular violin using her existing violin technique. The result is better sound in performance.

**Recorded sound:** Over the course of the project we have recorded new sounds several times. This has been based on an increased understanding of what works well with the system. We have found that sounds based on extended techniques work the best for our musical ideas.

**String orchestra:** Since all the sonic material is taken from the violin, the sonic result could easily have ended up sounding like an extended string orchestra. However, this has not been the result since the selected sound files were based on various types of extended techniques exploring the extremities of the sonic possibilities of the instrument. That said, we found it very inspiring to work with a system where it was possible for the performer to play along, or contrast, with similar sounding sonic material as she was producing herself. This type of *sonic transparency* made for a freer interaction between musician and computer.

**Fragmented sound:** Since the sound material was based on 250ms short sound fragments, it does not easily allow for creating longer sustained phrases. But by moving through the space it is possible to generate “phrases” based on the fragments, and connect them together while playing on top of them.

**Form:** The structure of the piece is based on a coarse path we have defined through the space. This is based on the idea of a referent-based improvisation, where a rough outline of the form is used as the basis for the sonic exploration.
Reflections

In this section we will discuss some general topics that have emerged from our development process.

**Simplicity:** Our experience with performing with electronics for more than 10 years each has shown us that we often create technologies and setups that are too complex. This again leads to performances that may be confusing to the audience. Our approach here can be seen as resonating with Maeda’s (2006) thoughts on simplicity: “simplicity is about subtracting the obvious, and adding the meaningful.” The development of Transformation has shown us that a seemingly “simple” setup can be very rewarding artistically.

**Freedom:** The simplicity in set-up, interaction and sonic control has given the performer freedom to move and improvise. Consequently Transformation is a piece she always looks forwards to playing.

**Room/stage/space:** Coming from a musical tradition, we are used to performing in traditional concert and chamber halls. In Transformation we have changed this by placing the bright, white stage in the middle of the audience. This gives a very strong sense of a physical space that the performer can move in and on. This way the stage becomes an “instrument” itself, a combination of physical, visual and sonic space that the performer can play with.

**Presence:** the fact that movements and position in space had an impact on the sonic result, made the performer’s presence on stage more focused than it often is in musical performances. This has made us reflect on the challenges involved when the musician enters into the domains of dance and theater. However, we have chosen to stay firmly in a musical tradition. The movement of the performer on and around the stage are purely motivated by that of producing sound, either electronically or on the violin. The performer has no training in dance or theater, and we have not
been interesting in moving in that direction. As long as this is shown clearly, we believe that the movements of a performer on stage are beautiful in themselves, albeit at a different aesthetic level than what would be expected from a dancer or actress.

**Performing in the air:** A challenge of working with video analysis as a controller is the lack of resistance and feedback in the “instrument.” However, in our current setup this felt less problematic since the electronic sound was so tightly connected to physical location on the floor. After rehearsing for a few hours at a time, the performer developed an embodied sensivity of where to find certain sound objects. This made her able to walk directly to the location she wanted, and also choose a trajectory to the point that would fit with the musical ideas she had in mind.

**Sound-producing actions:** We can talk about two levels of sound-producing actions: 1) actions involved in playing the electric violin, 2) action used to produce electronic sound. The latter group can again be subdivided into actions related to: a) playing on the violin, b) moving the head/arms while standing stationary, c) “ghost”-playing with the bow in the air, d) moving on stage. All of these were used in performance, but category c) less than the others. We explored “playing” with the bow in the air, but this turned out to lead to more of a theatrical performance, something we were not interested in pursuing at this stage.

**Future work**

There are, of course, many possibilities for further refinement and development that will be explored in future research:

**Tracking:** We will explore using high-speed and high-resolution cameras to improve the response time of the system. We will also continue to explore other
types of tracking solutions, while at the same time keeping in mind our focus on simplicity in both technology and concept.

**Micro-level:** With more precise tracking it is possible to start exploring how very subtle movement, what can be called *micro-movement*, may be used to control the system. We have received many comments on the tension seen when the performer stands still, since everyone knows that movement will produce sound. It will be interesting to explore this type of tension further with more precise tracking.

**Multiple performers:** The system can also be expanded to track two or more performers. The challenge here is not so much on the technical side, but more on the conceptual. We will start by exploring how an extra instrumentalist or dancer will work with our current ideas.

**Visuals:** The last two performances of Transformation have been highly visual, with the white, bright square on the stage setting up the performance space. While we like the simplicity of the current setup, we will also explore adding some subtle visuals on the floor.

**Localized sound:** In previous performances the sound of the electric violin has been spatialized together with the electronic sound. We want to see how a ceiling mounted speaker may be used to project the sound of the violin from above. Such a separation between violin and electronic sounds may be positive, but it may also remove some of the current blending between the two layers of sound.

**Live sampling:** Rather than starting with pre-recorded sound files, we will explore starting with an empty sonic space and then gradually fill it as the performer moves and plays in the space.

**Stillness and quietness:** One of the most important challenges is for the performer to keep the focus on holding back on the physical movement, so it is possible to keep the piece still, quiet and contemplative.
References


