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Strings P

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Strings **is an audiovisual performance for an acoustic violin and two generative instruments, one for creating synthetic sounds and one for creating synthetic imagery. The three instruments are related to each other conceptually, technically, and aesthetically by sharing the same physical principle, that of a vibrating string. This submission continues the work the authors have previously published at xCoAx 2020. The current submission briefly summarizes the previous publication and then describes the changes that have been made to** ***Strings*****. The P in the title emphasizes, that most of these changes have been informed by experiences collected during rehearsals (in German** ***Proben*****). These changes have helped** ***Strings*** **to progress from a predominantly technical framework to a work that is ready for performance.**

Fig. 1. Rehearsal Still

Introduction

Strings represents the newest iteration in a series of works by the authors that combine acoustic and synthetic instruments in an open improvisation setting. This openness is complemented by generative principles that are shared by all instruments. The principles affect the interaction among the instruments and their means of producing acoustic and visual output. This establishes a strong aesthetic correlation even during moments of free and independent play. In *Strings*, the shared principles are based on the physical phenomenon of a vibrating string. In case of the acoustic instrument, a violin, this principle forms part of its natural sound production mechanism. In case of the synthetic instruments, this principle is translated into computer simulations that operate as generative mechanisms for creating synthetic sounds and images.

A first version of *Strings* has been described previously (Bisig and Wegner 2020). This earlier publication focused on the academic and artistic contexts that inform the work and the details of its technical implementation. This came at the cost of a missing discussion of a rehearsal. The current submission rectifies this by highlighting how observations made during rehearsals inspired further developments. The remainder of this text is structured as follows: the "Background" and "Implementation" sections of the previous publication are briefly summarized, the insights gained during rehearsals and their influence on further developments are presented, and possible future directions for research and development are outlined.

Background

The realization of *Strings* is inspired by two different applications of generative techniques: their integration as elements of control for a digital instrument and their use to create correlations between different media.

Interactive generative systems, especially those that are based on the simulation of familiar natural principles, can respond to interaction in a manner that is easy to understand. This effect can be exploited to improve the naturalness and intuition of interacting with digital instruments (Mulder and Fels 1998, Pirro and Eckel 2011, Castet 2012). Furthermore, generative systems can potentially exhibit complex behaviours. This reduces their level of predictability, which in turn offers possibilities for exploration and experimentation (Johnston 2009).

Generative systems can be used to concurrently control the creation of different media. This provides interesting opportunities for collaboration among artists (Bisig and Kocher 2013, Alaiou etal. 2014), can establish aesthetic correlations among the different media (Momeni and Henry 2006), and exposes to an audience the underlying generative principles (Momeni and Henry 2006, Johnson 2009).

Implementation

An overview of the main technical components and their control by three performers is shown in Fig. 2. *Strings* combines two generative systems that simulate the vibration of strings by means of a mass-spring-damper model. The simulated strings are used to control the creation of synthetic sounds and images.

The activity of both generative systems is predominantly controlled by the violinist. The violinist's visual appearance and acoustic output are recorded by a camera and a microphone, respectively. The camera image is analyzed by detecting salient image points. These points are tesselated into a triangulated surface which serves as basis for constructing a mass-spring system that in turn controls the creation of synthetic images. The microphone recording is analyzed by calculating a frequency spectrum. Based on the energy in each frequency bin and the consonance relationships among them, a subset of bins is selected. These bins are then used to excite through a simulated resonance effect the simulated strings in both generative systems.

The generative system that controls sound synthesis simulates several one-dimensional arrays of interconnected springs. The topology of these arrays is defined in advance and doesn't change during simulation. The generative system that controls image synthesis simulates two-dimensional meshes of interconnected springs. These meshes are created from a live camera image and their topology changes dynamically.

The simulated springs are translated fairly directly into acoustic and visual output. The spring arrays are sonified by mapping the deflection of mass-points into amplitudes of a waveform. The spring-meshes are visually rendered as triangulated surfaces whose coloring and opacity is controlled by the live camera image and the amplitude of the springs' oscillations, respectively.

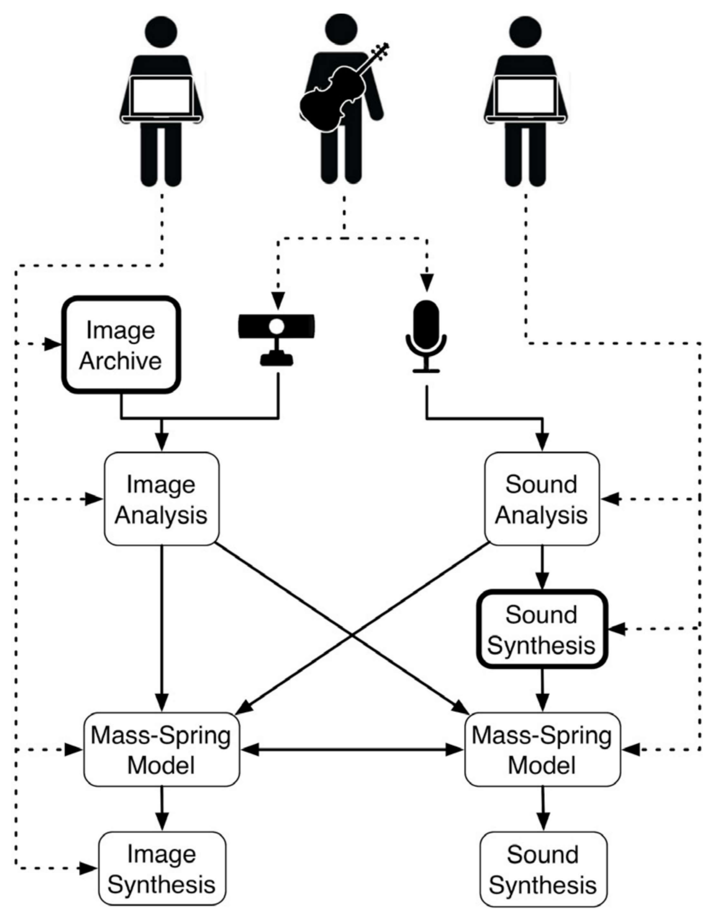

Fig. 2. Implementation. The schematic figure depicts the main technical components of Springs. Solid arrows represent data flow between these components. Dashed arrows represent interactive controls by the performers. The components represented by boxes with thin outlines were already part of the original implementation. Components shown as boxes with thick outlines were newly developed.

Rehearsal and Development

During last year, the authors have extensively rehearsed Strings. A visual impression of a rehearsal is shown in Fig. 1. Several excerpts from video recordings of these rehearsals are available online.[1][2][3] The purpose of these rehearsals was

1. Video Excerpt 1
2. Video Excerpt 2
3. Video Excerpt 3

three fold. 1) To familiarise the violinist with the interactive controls and the synthetically produced media. 2) To establish an iterative process of continued development and evaluation. 3) To devise an outline for a performance structure.

This submission focuses on the first two aspects.

During rehearsals, it became apparent that the mechanisms for establishing a correlation between the activities of the violinist and the generative systems worked so effectively that it was to the detriment of the aesthetic richness of the performance. Furthermore, it also became evident that the level of interactive control among the three performers was too heavily tilted towards the violinist. As consequence, the synthetic outputs of the generative systems mostly mirrored the visual and acoustic presence of the violinist.

Based on these observations, several adaptations have been made to the generative systems. In the following description, the adaptions are grouped into those that increase aesthetic diversity and those that re-balance interactive control.

Aesthetic Diversity

The generative system that produces synthetic audio has been altered in several ways. The number of strings that can be modelled was increased by porting parts of the implementation from CSound to C++ . This offers the possibility to concurrently simulate a large number of strings with only some contributing to the audible output while the others remain muted. Thanks to this, an *archive* of sonically diverse strings can be prepared ahead of time and then selectively chosen from during the performance. Another change concerns the mechanism of excitation of the simulated strings. In the original version of *Strings*, the spectral analysis of the microphone recording directly excited the simulated strings. This direct excitation has been abandoned by introducing an additional sound synthesis layer that mediates between spectral analysis and string oscillations. The additional layer combines several simple sound generators including sine oscillators, impulses, impulse chains, and white noise. These generators are controlled by the spectral analysis. The generators' output is then used to excite the simulated strings. Via this indirect excitation, the simulated strings can reproduce a wider range of acoustic phenomena, such as plucking and bowing.

The generative system that produces synthetic images has also been modified. One modification concerns the image material that serves as input for creating a two-dimensional mesh of simulated strings. Rather than to rely solely on the live camera image for this purpose, additional images can now be retrieved from a collection of pre-stored images and combined with the camera image. The purpose of this modification is similar to that of employing an *archive* of pre-configured simulated strings for sound generation. It permits to create a collection of source images and processing settings that can be tested ahead of time for their capability to generate a wide diversity of visual results. As second modification, an additional mechanism for controlling the movement of the simulated springs has been devised. The mechanism introduces forces that make the simulated mass-points move at pre-determined velocities. Depending on the mass-points' interconnection by springs, this mechanism causes the meshes to organise into multiple regions that exhibit different rotational movements. As a result, the diversity of behaviours of the image generating system increases.

Interactive Control

Several of the previously described modifications have been implemented not only for the purpose of increasing aesthetic diversity but also to shift the balance of interactive control.

The presence of an intermediate sound synthesis layer replaces the direct relationship between the violinist's acoustic output and the synthetically generated sounds by a more flexible correspondence. This offers more opportunities for interaction for the laptop-performer who can freely select during the performance which of the intermediate sound synthesis systems responds to the violinist's acoustic output and excites the simulated strings. The availability of an *archive* of pre-designed simulated strings frees the laptop-performer largely from concerns that the interactive manipulation of the simulated strings causes the simulation to become unstable. The archived strings can be tested ahead of a performance for their stability. Furthermore, currently sounding strings don't need to be strongly modified to obtain different acoustic results. Instead, such results can be achieved by selectively un-muting strings from the *archive.*

The establishment of an *archive* of images that serve as source material for creating simulated string meshes and the addition of forces that cause the mass-points to move at pre-defined velocities have made the synthetic image generation process more flexible and independent from the activities of the violinist. Accordingly, these aspects offer more opportunities for creative experimentation by the laptop-performer. The performer can chose different source images and thereby influence the generated spring meshes independently of what is happening on stage. Furthermore, the performer can combine resonance-based string oscillations with directly controlled mass-point velocities and thereby alter the dynamics of the resulting synthetic image.

It's important to mention that these changes have not only shifted the balance of interactive control among the performers, but they have also established two different levels of interaction. On a regular level, interactivity controls some of the properties and behaviours of the generative systems. This level has already existed in the first version of *Strings*. But in addition, a meta level of interactivity has now become available. This meta level controls to what extent regular interactivity is shifted from the violinist to the other performers. These changes have a large impact on the improvisation situation.

Outlook

The authors expect that additional performances and rehearsals will inspire further improvements of the generative systems. Under the assumption that the setup with its three distinct instruments remains the same, the authors envision the following modifications.

Currently, the meta level of interactivity is exclusively available to the laptop performers. This level of interactivity should also be made accessible for the violinist. But for this, additional gestures by the violinist need to be integrated as control cues. It might be useful to employ non-sound producing gestures for this purpose. But the camera and microphone based tracking that has been used so far is ill suited for this task. It is complicated to analyze a camera image for specific gestures and non-sound producing gestures can't be recorded by a microphone. For this reason, the authors plan to integrate wearable sensors such as inertial measurement units and/or respiration sensors into the stage setup.

Concerning the diversity of the synthetic outputs, the approach followed by adding a mediating sound synthesis layer warrants further exploration. This approach is attractive since it preserves the functional and aesthetic coherence between the acoustic and digital instruments and simultaneously expands the diversity of results. The authors plan to investigate how this approach can also be adopted for the image producing generative system.

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