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# SOUND FOREST/LJUDSKOGEN: A LARGE-SCALE STRING-BASED INTERACTIVE MUSICAL INSTRUMENT

**Roberto Bresin, Ludvig Elblaus**
**Emma Frid, Federico Favero**
KTH Royal Institute of Technology
{roberto, elblaus
emmafrid, ffavero}
@kth.se

**Lars Annersten**
**David Berner**
Musikverket
{lars.annersten,
david.berner}
@musikverket.se

**Fabio Morreale**
Queen Mary University of London
f.morreale
@qmul.ac.uk

## ABSTRACT

In this paper we present a string-based, interactive, large-scale installation for a new museum dedicated to performing arts, Scenkonstmuseet [1], which will be inaugurated in 2017 in Stockholm, Sweden. The installation will occupy an entire room that measures 10x5 meters. We aim to create a digital musical instrument (DMI) that facilitates intuitive musical interaction, thereby enabling visitors to quickly start creating music either alone or together. The interface should be able to serve as a pedagogical tool; visitors should be able to learn about concepts related to music and music making by interacting with the DMI. Since the lifespan of the installation will be approximately five years, one main concern is to create an experience that will encourage visitors to return to the museum for continued instrument exploration. In other words, the DMI should be designed to facilitate long-term engagement. Finally, an important aspect in the design of the installation is that the DMI should be accessible and provide a rich experience for all museum visitors, regardless of age or abilities.

## 1. INTRODUCTION

The realization of interactive installations in museums and science centers has become increasingly popular throughout the past two decades [1, 2]. Such installations may engage visitors, provide rewarding experiences that stimulate learning and motivate visitors to return to the museum. In this paper we present a new installation for a new museum dedicated to performing arts, Scenkonstmuseet [1], Swedish Museum of Performing Arts, which will be inaugurated in 2017 in Stockholm, Sweden. The museum will be organized in three sections: Dance, Theater and Music. The installation presented in this paper will be part of the Music section and will consist of a large-scale digital musical instrument (DMI) [3]. The DMI will occupy an entire room which measures 10x5 meters. The installation is the result of collaboration between the Swedish Museum of Performing Arts and KTH Royal Institute of Technology in Stockholm, Sweden. In the following section we briefly describe the theoretical framework that has served as foundation for our design decisions, followed up by a detailed description of the Sound Forest installation.

[1] http://www.scenkonstmuseet.se



## 2. BACKGROUND

### 2.1 Collaborative Musical Interface Design for Novice Players

The Sound Forest installation should not only provide a rich musical experience for the single novice player but also enable collaborative musical experiences. When designing collaborative experiences for novice players in public settings, one should strive to achieve a balance between simplicity and virtuosity while at the same time minimize the time required to learn how to use the interface [4]. The trade-off in determining the appropriate balance of complexity and expressivity of a musical interface is not easily resolved [5]. Designers of interfaces for musical expression for public settings usually address the need to cater to novice users by restricting the musical control. It has been suggested that providing novices with easily accessible music making experiences is more important than providing complex interfaces with upward capability for virtuosic expression [5] in this context. As discussed in [6], limiting the number of features in the design of a musical interface can be beneficial for the performer.

Nevertheless, in order to encourage long-term engagement, the initial ease of use should be coupled with a long-term potential for expansion to virtuosity, as suggested in [7]. In general, activities which remain engaging in the long term are often characterized by a trade-off between ease of learning and long-term power and flexibility [8]. Engaging, flow-like [9] activities such as music are characterized by being at an appropriate level of difficulty [10]. The interaction in the Sound Forest should be designed in such a manner to avoid "dead ends" [10]; the complexity of the instrument should provide a possibility for unlimited growth and encouragement.

### 2.2 Accessible Interactive Musical Interface Design

The underlying premise of most collaborative interface design is that playing music can be made accessible to nonmusicians through the use of various design constraints [5]. The term accessibility in this context does however not only involve designing for novices, but also for people with impairments. There are numerous examples of research exploring approaches for customizing musical interfaces to people with impairments (see e.g. [11–16]). There are also examples of "accessible" music interfaces, such as e.g. *Skoog* [2] and *Soundbeam* [3].

It is important to note that an inclusive design approach is preferable when designing for sensory impaired; design issues should considered at the beginning of the design process, so that the design is done for the visitors abilities, rather than compensating for their disabilities [17]. It has been found that children with learning disabilities were able to do their best when presented with learning and creating music in a multisensory learning environment and that "the better functioning modes of learning helped the child to compensate for the dysfunctioning modes" [18]. The Sound Forest will provide the player with multiple modes of interaction. This multimodal property of the room, in which sound, visual and haptic feedback will be provided, is one aspect that we believe will lead to inclusion of different visitor groups.

## 3. THE SOUND FOREST - LJUDSKOGEN

Some design requirements and constraints were defined by the curators of the museum in the initial stage of the development process of the interactive installation. The installation should be designed in such a manner that it enables visitors without any prior knowledge of musical instruments to engage with the DMI in a rewarding way. A key concern is to create a digital instrument facilitating intuitive musical interaction enabling visitors to quickly start creating music either alone or together. The interface should also be able to serve as a pedagogical tool; visitors should be able to learn about concepts related to music and music making by interacting with the DMI. Since the installation will be set at the museum for a period of five years, one important aspect is to create an experience that will encourage visitors to return to the museum to continue to explore the instrument. The design of the installation shall focus on sustaining long-term engagement with the system. Finally, an important aspect of the installation is accessibility; ensuring that the installation is not only easily accessible for people with impairments (e.g. blind, deaf or visitors with impaired mobility) but also able to provide a rich experience for these visitors. The room itself should not create barriers that hinder persons with impairments to engage in a musical experience.

After a period of about six month during which we had several discussions and brainstorming meetings about how to comply with the requests from the curators, we came up with the idea of an installation based on a string metaphor. Several researchers and artists have user the "string" as controller in different installations and new DMIs, such as the *Manipuller* [19, 20], the Web (by Michel Waisvisz [21]), the *STRIMIDILATOR* [22], the *Vocal Chorder* [23], *Global String* and *the SoundNET* [24], to name a few.

A string has clear affordances well known by most of the museum visitors and invites to different types of interaction such as plucking, bowing, punching, pulling, pushing, scraping and brushing. The central idea was to create an interactive music room that could serve as a traditional acoustic string instrument in which long strings attached to the ceiling and floor would serve as a control interface. As a metaphor of traditional acoustic string instruments, we wanted the movements and feeling when interacting with the strings to be tightly connected to the quality of the sound and the physical interaction. The main idea was that energy provided by body gestures performed by visitors when interacting with the strings would be translated into energy, affecting the acoustic properties of sound and of other perceptual modalities such as haptic feedback and lighting. The presence of sound, lights and visual effects as well as haptic feedback will support the intentions of the players and reinforce the perception of a highly responsive system. The final goal is an installation that quickly and intuitively provides the feeling of being a musician. This includes being able to play and create music both on your own as well as together with other visitors. A sketch of the final installation can be seen in Figure 1. We aimed at creating a setting inspired by a forest in which strings would serve as metaphoric trees which, with help from lightning design, would create a mystical setting (see conceptual sketch in Figure 2). The installation room was named Sound Forest (or Ljudskogen, in Swedish). In the following sections we describe the different components used for creating the interactive strings more in detail.

Our work is novel in the sense that, to the best of our knowledge, no prior large-scale multisensory installation has explored aspects of multimodal interaction in a collaborative setting involving multiple mono-cord ceiling-to-floor strings. The fact that the installation will be in place for five years will enable us to run multiple player studies involving different visitor groups (age, abilities, size, education) making it possible to investigate thousands of users, also in longitudinal studies over the 5-year period. Sound Forest will enable us to study how the room could be used for educational purpose, such as e.g. for improvising music in a group setting, or appreciating different sounds generated through different synthesis models.

## 4. CONCEPTUAL DESIGN AND PROTOTYPING

As briefly presented above, the requirements by the museum curators and pedagogues for The Sound Forest can be summarized as follows: the design and realization of the installation should:

- *Enable* interaction, creativity, participation, engagement
- *Foster/promote* learning, education
- *Include* different user groups

The instrument should be:

[2] http://skoogmusic.com/
[3] http://www.soundbeam.co.uk/

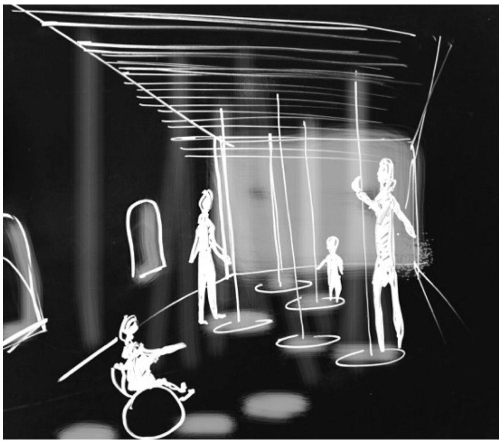


**Figure 1**: Sketch of the final installation with five strings, vibration platforms underneath each string, and glowing light emitted by each string.

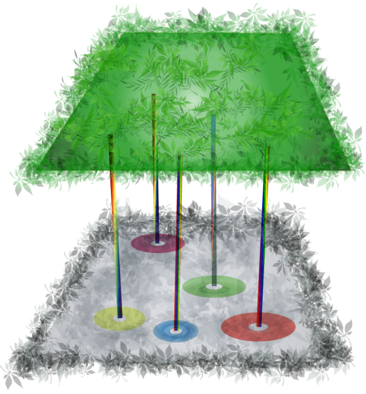


**Figure 2**: Conceptual sketch.

- *Scalable*: functioning for one single player as well as for many players; expandable in order to enable creative development
- *Intuitive*: clear affordances
- *Collaborative*: allow interaction of several people at the same time
- *Accessible*: visitors should be equally able to use the instrument, regardless of age and/or abilities
- *Easy to maintain*: about 12 000 visitors per month will be visiting the museum

These specifications will be met also by taking into account the tight connection between sound and music and motion as emerged from several research projects during the last 20 years [25,26]. Specifically, it is not possible to generate sounds with an instrument without engaging in some form of body motion that injects energy into the instrument.

### 4.1 Design of One String

The instrument that we envision in this project has a mono-cord string as its basic element and metaphor. Strings provide affordances that do not need explanations; they allow for intuitive and immediate use. In order to realize the objectives of the project we will create augmented strings which allow interaction, creativity, participation, and engagement. The mono-cord strings will have the following characteristics:

- String material: LED light intertwined fiber optic cable with DMX controller
- Sensors detecting the string movements and vibrations
- Sensors detecting hand position on the string
- Sound generation: the sound will be provided through a directional loudspeaker positioned on the top of each string
- Haptic floor: a vibrating platform placed below each string that will be activated through interaction with the string itself

#### *4.1.1 String Sensors*

The string installation will, from a conceptual perspective, be divided into two parts: the installation and the collection of content. The installation comprises all the hardware and software that is needed to provide feedback, such as light, sound, and vibration, and gather data from the interaction. The collection of content can be seen as a repertoire, e.g., a set of musical works, études, pedagogical examples, perceptual experiments, that can be loaded into and performed in the installation. Creating the content will be an evolving long-term process that will include commissioning pieces by composers, inviting students to create experiments, and prototyping new forms of interaction as a component in interaction design and sound and music computing research. The project ambition is to be able to deliver more than a fixed piece and instead aim to provide a platform for further development, i.e. an instrument, rather than a fixed installation.

To support such wide-ranging activities, a broad strategy for data gathering is adopted. Each string will be fitted with a set of sensors: a high quality, full bandwidth, contact microphone; a high resolution accelerometer, at the top end of the string; and ultrasonic distance sensing, possibly both from the ceiling and the floor, depending on the emission angle of the sensor used. The possibility to weave custom sensing materials into the strings themselves, allowing for e.g. capacitive sensing, is also currently being explored. These sensors will be connected to appropriate control and capture hardware, made up of single-board computers such as Arduino or the Raspberry Pi, fitted with suitable analog to digital converters, voltage dividers, or other necessary circuitry.

All of the data, from all of the sensors, will be collected and made available for the content creators in a unified form as Open Sound Control-formatted data. In addition to the raw data, some high level features will also be computed, such as level of activity in the room, to aid content creators to interpret the wealth of data that the installation will produce.

The Sound Forest will be organized as a synchronous (real-time) centralized network [27], allowing players to interact through strings that do not have direct influence on each other. Data from players will be sent to a computerized hub for analysis and generation of musical output.

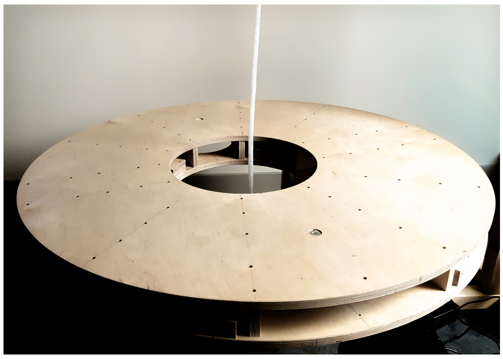
#### *4.1.2 Haptic Floor*

The potential of integrating vibrotactile feedback into DMIs has been stressed in numerous previous studies [28, 29]. Vibrotactile feedback has been found to increase controllability of certain musical processes [30]. Haptic feedback will be used as a complement or to reinforce the emitted sounds in the Sound Forest, thereby enhancing the player's musical experience. We suggest to re-produce the situation of a regular acoustic instrument in which the instrument's body amplifies the sound produced by the vibration of the sound-generating mechanism (in our case, the vibration of the augmented string). The idea is to re-recreate such a closed loop between user interaction and haptic rendering by placing a vibrating wooden platform underneath the augmented string. The platform will react to gestures performed on the string. Vibrating floor surfaces are accessible to a wide range of users [31] and therefore go well in line with the design constraints placed upon the Sound Forest.

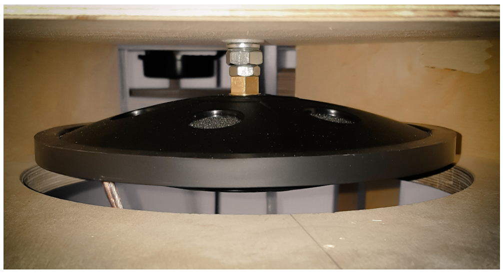
The haptic floor should be designed to fulfill the following requirements:

- Provide low-latency feedback on the interaction with the string
- Enable tactile translation [32] of musical sounds emitted by the DMI as well as tactile synthesis of customized haptic feedback
- Transmit frequencies that overlap with the sensitivity domain of FA II receptors in the feet
- Produce perceptually relevant feedback for a wide range of visitors (despite floor deformation due to weight)
- Produce enjoyable vibrotactile feedback: ensure safe whole body vibration, according to the ISO 2631 standard [4]
- Reduce transmission of undesirable structure borne noise: has to be fully decoupled from the floor around and beneath it

A prototype of the first iteration of the vibrating platform can be seen in Figure 3. The prototype consists of a birch-plywood circular surface with a radius of 60 cm under which vibrating actuators (one Clark Synthesis TST239 Silver Tactile Transducer Bass Shaker and one Sinus Live BassPump III bass shaker, for comparative purposes) are fixed on each side of the string. In order to fully understand how to display vibrations to the player in a meaningful way, so that the haptic feedback is tightly coupled to the music, we must first investigate the physical capabilities of



(a)



(b)

**Figure 3**: Prototype of the first iteration of the vibrating platform. (a) Vibrating platform, removed from the main floor structure. (b) Clark Synthesis TST239 Silver Tactile Transducer Bass Shaker mounted in the platform structure, seen from the side.

the vibrating platform. As expected, initial measurements done to characterize the frequency response of the platform showed some undesirable resonance peaks that were audible at high amplitudes. Accelerometer measurements on sweeping sinusoids also indicated that the structure of the platform might be too rigid to be fully excited by the current actuator setup. A continuation of the work involves exploring different setups using a tile structure with damping rubber feet, which will both allow the structure to vibrate freely while at the same time support the weight of multiple players standing on top of the platform. The future version of the platform will of course make use of two identical actuators; this will allow for exploration of phase and time delays in order to emphasize specific platform resonances.

#### *4.1.3 Lighting Design*

In order to provide a stronger feedback to users while interacting with the strings, we plan to use a LED light intertwined fiber optic cable with DMX controller. Each string, anchored on both floor and ceiling, will change light according to the physical excitation that it receives (e.g. plucking, scraping), with real-time response to user actions. The string should be designed with the following requirements in mind: change colour/intensity/frequency of the lighting feedback in real time when touched/moved by the player, reflect the real-time changing sound properties with changes in the lighting scenario and be robust to different interaction strategies by the museum visitors (e.g. climbing, hanging, strong percussive and plucking

[4] http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=7612

gestures). When the first prototype of the string has been implemented and the overall lighting concept has been accepted, focus will shift to the detailed lighting design solution for the whole room. The room lighting design will follow the following requirements:

- Give an overall perception of the soundscape
- Provide an "idle" status of the room
- Engage/raise interaction of the audience
- Allure people to access the room

### 4.2 Evaluation

During the first six months of prototyping, an initial string prototype was constructed and evaluated through experiments with a set of users who were allowed to spontaneously explore the string. The design process was iterative: starting from the initial idea, a number of low-fidelity prototypes were developed, formally evaluated, and refined using the collected feedback. Results from these experiments are reported in [33] in which we analyse the types of interaction that were found for users of different age groups (from children to adults) by applying conventional HCI methods.

## 5. FUTURE DEVELOPMENTS

Once the final installation will be deployed, we will conduct a field investigation from the point of view of the visitor experience. We will apply a multi-method evaluation strategy [34] of different techniques to examine the audience behavior (e.g. log-data analysis, video-cued recall, interviews, questionnaires, observation studies). These formal evaluations techniques will be adopted in order to investigate how appreciated the installation is by visitors at the museum as well as to evidence potential strengths and weaknesses of the system. Findings will be used to adapt the system and to contribute to new knowledge on visitor experiences with interactive artworks, the latter being something we consider to be important given the increasing interest of the interaction design community in the field of interactive art. The Performing Arts Museum and the Sound Forest installation will be inaugurated in early 2017. About 12 000 visitors per month are expected to visit the museum.

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