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Comments

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Furthering Development of Smart Fabrics to Improve the Accessibility of Music Therapy

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ABSTRACT

In this paper, we present the design and development of HarmonicThreads, a smart, cost-effective fabric augmented by generative machine learning algorithms to create music in real time according to the user's interaction. In this manner, we hypothesize that individuals with sensory differences could take advantage of the fabric's flexibility, the music will adapt according to users' interaction, and the affordable hardware we propose will make it more accessible. We follow a design thinking methodology using data from a multidisciplinary team in Mexico and the United States. Then we will close this paper by discussing challenges in developing accessible smart fabrics in different contexts.

CCS CONCEPTS

• **Human Centered Computing**; • **Empirical Studies in Ubiquitous and mobile computing**;

KEYWORDS

Human Activity Sensing, Sensing Devices, Interactive Textile, Sensing, Musical Interaction, Inclusion, Flexible display

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1 INTRODUCTION

Singing and playing musical instruments support childhood development [10]. Through music, children can learn to express themselves and communicate with others, thereby enhancing their social and emotional skills [2, 3Hallam]. However, traditional musical instruments demand excessive cognitive load and musical training, which introduces a challenge for some groups, including children with disorders affecting motor, sensory, and attention skills [6]. Therefore, novel solutions should be explored to make musical interaction more accessible.

With the development of new devices and sensors, natural user interfaces (NUI) have expanded user-computer interaction beyond the capabilities of graphical user interfaces and command line interfaces [7]. NUIs allow users to interact appropriately with content simply by using pre-existing skills [7]. These include general human skills, such as eye contact, facial expressions, pointing, or touching and manipulating objects. By applying those skills to an interface design, NUIs can allow for more complex and seamless interactions with digital objects in the physical world [7].

According to NUI literature, elastic displays, interactive surfaces made of deformable materials, are productive tools for musical interaction [4, 13, 16, 17]. The malleability of elastic displays allows users to interact with digital content simply by pushing, pulling, twisting or tapping a fabric. When combined with audio and visual stimuli, elastic displays provide a positive user experience and enhance learning for diverse individuals.

Creating a positive user experience is especially plausible if our visual and auditory outputs are personalized and tuned according to the user's needs. Therefore, novel approaches of Artificial Intelligence (AI) and Machine Learning (ML) have been explored in both areas of music generation and refined capacitive touch sensing to personalize and generate music [15].

In this research project, we are working to develop HarmonicThreads, a cost-effective and smart elastic display. Through AI and ML algorithms, HarmonicThreads adapts to the needs of diverse users and facilitates musical interaction. In this paper, we present the current design and development of HarmonicThreads and its potential in augmenting musical interaction by using generative machine learning models.

2 RELATED WORK

Deformable interfaces allow users to vary the amount of pressure applied when touching, creating permanent or temporary deformation [9]. This extra dimension of interaction can potentially improve the musical experience [1, 4,16,17]. For example, Al-terity [11Tairoğlu,] is a non-rigid musical instrument that uses machine learning to generate new audio samples for real-time audio synthesis. Authors hypothesize that using machine learning models could enhance the exploration of performing music in response to the deformation of the musical instrument. Another example is FabricKeyboard [14], a fabric-based musical controller that detects touch, proximity, pressure, and stretch using conducting threads, allowing a unique tactile experience.

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Deformable surfaces are overall engaging and appropriate for musical interaction. However, little has been said about developing cost-effective, portable interfaces to support diverse individuals in more diverse contexts. In the literature, two main approaches have been explored in designing the sensing ability of the smart fabric: indirect optical sensing using depth cameras and direct sensing using capacitive touch sensor boards and conductive threads. While the depth sensing approach computes the distance of pixels from a camera module, capacitance sensing detects the interaction based on the disturbance of a circuit [5].

Optical sensing approaches require additional hardware and cameras specialized in measuring depth. Therefore, they demand careful calibration work and introduce plenty of room for error. Instead of relying on a sensor separate from the fabric, capacitance sensing involves conductive threads sewn into the fabric itself. Because it reduces the need for additional hardware components and the probability of error, we use capacitance sensing in this project.

3 METHODS

We follow the design thinking process to develop and evaluate a cost-effective smart fabric augmented with musical and tactile capabilities allowing diverse children to interact and create music. First, to empathize and define stages, we analyze a qualitative database of interviews conducted in Mexico and the United States about designing and evaluating an elastic display supporting Autistic and preschooler children [14]. For the ideation stage, we conducted brainstorming sessions to propose solutions that were affordable, easy to use, and accessible. Currently, we are developing a prototype that we will evaluate in the future in both contexts of Mexico and the United States.

4 HARMONICTHREADS

HarmonicThreads is a smart, cost-effective fabric augmented through the application of ML and AI. It will use generative machine learning algorithms to create music and display animations in real time according to the user's interaction. We hypothesize that by using capacitive sensing and generative ML algorithms, we could create a more inclusive and accessible solution for musical interaction.

4.1 Requirements

After the data analysis of interviews previously conducted in Mexico and the United States, we found out that smart fabrics aimed at supporting musical interfaces for diverse users in different contexts must contain personalized and multisensory feedback. They should also be affordable to accommodate as many individuals as possible.

To improve the experience of diverse users, we found that a multisensory experience could better support their diverse needs. Therefore, our tool provides auditory, visual, and tactile feedback when the fabric is manipulated. The user's interaction with the fabric should directly manipulate the multisensory stimuli to give individuals a sense of control over their interaction, facilitating their sensory and motor responses [8]. Given that different individuals may experience different needs in terms of sensory experience and music, our tool will use generative machine learning algorithms to create music in real time according to the user's interaction. In this manner, the music will adapt according to users' interactions. Finally, to make our prototype more accessible for all, we plan to use affordable and portable hardware.

4.2 Design and Development: Physical Fabric Interface

Currently, our design is composed of a capacitance-sensing, flexible fabric. Like an Arduino matrix keypad, capacitive touch circuits rely on the effect of a finger or body part on a circuit [5]. In essence, our HarmonicThreads system combines a capacitive touch circuit into a fabric. Research has shown that fabrics constructed with conductive materials, such as stainless steel or copper threads, offer great potential in facilitating the integration of 'soft' networks into fabrics [12]. Thus, conductive materials give ordinary fabrics the ability to sense and respond to stimuli such as touch or temperature [12]. By designing our system with capacitive touch sensor boards, conductive thread, and flexible fabric, we develop a smart fabric that serves as both a touch sensor and output display. This not only eliminates the need for extra motion-sensing hardware, but it also improves user-computer interaction and provides a more effective means of learning.

In the development of our prototype, conductive threads are sewn onto a flexible fabric, then attached to a capacitive touch sensor board with wires (Figure 1). The touch sensor is then connected to an Arduino Nano, which runs the program through the Arduino IDE allowing us to both track and 'sense' precise locations on the fabric. Using a USB cable, the program is uploaded to the Arduino Nano from a Raspberry Pi, a minicomputer. Because Python is an efficient, easy to use programming language, and it allows the flexibility to import a variety of libraries that are compatible with our project, the code for HarmonicThreads is developed through the Raspbian system and Thonny Python interface. After sensing the user's touch and processing the sensor data through the software, the output will be expressed using speakers and a mini projector. Figure 2 demonstrates the layout of our prototype component architecture. We hypothesize that if we use this approach, we can increase the portability and performance of our design.

Having the threads sewn in a particular arrangement on the fabric is important to ensure proper location tracking. HarmonicThreads can detect and locate the user's touch with a fabric by measuring any alterations in capacitance at each addressable electrode [5]. In other words, capacitive touch circuits rely on the disturbance a finger or body part has on a circuit, and the address of that disturbance can be tracked [5]. We create these "addresses" in our design by using two arrays of conductive thread traces to activate a capacitive touch sensor breakout board (Figure 3). By following a grid pattern, that is, sewing conductive threads in rows and columns, we hypothesize that the location of the touch can be detected by computing the X and Y coordinates. This essentially allows us to create touch switches out of conductive thread.

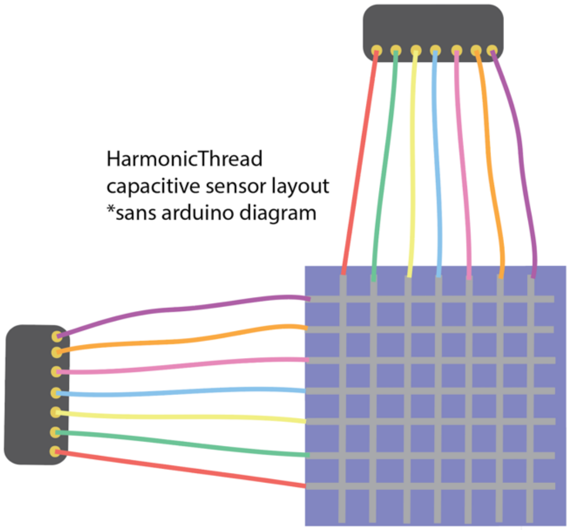

Figure 1: Fabric Capacitance Sensor Layout

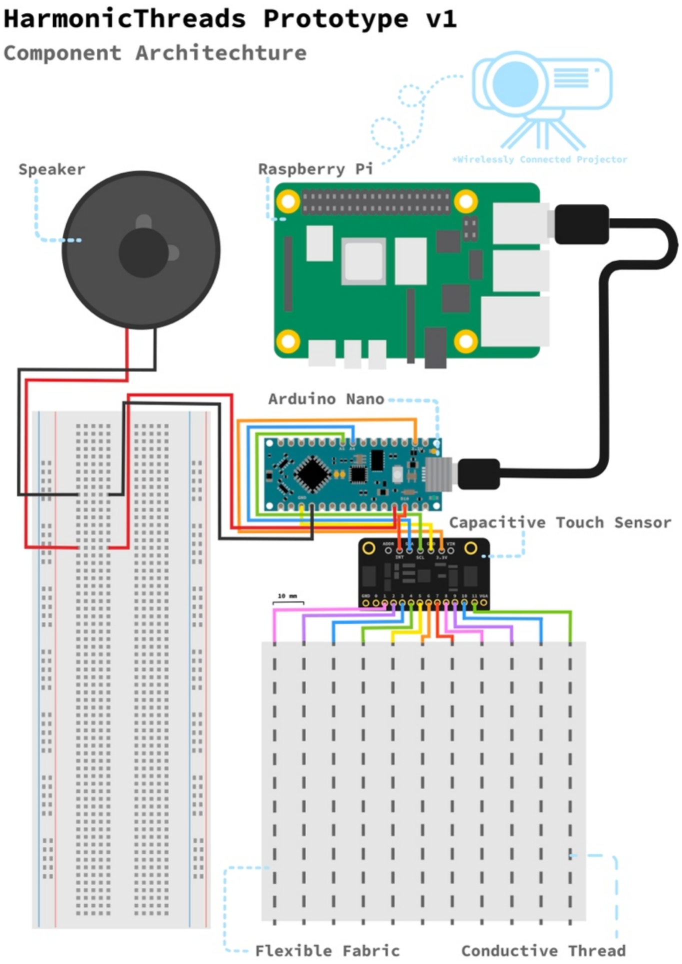

Figure 2: HarmonicThreads Component Architecture

4.3 Design and Development: Music Generation with Machine Learning

Deep Learning serves as a powerful tool for predictive analysis in many real-world situations, and we use it in this case to generate music notes. So far, two deep learning approaches have been explored to generate music. In the first approach, a dataset of 90 MIDI audio files of piano music is used to train an LSTM neural network model to predict piano notes that sound pleasing based on the previous notes. A training set for the neural network is created by extracting notes and chords from the MIDI files and mapping them to numbers. After the model has been trained, it could be used to produce new pieces of music. We can use this model in our design to produce a variety of music notes based on the user's interaction with the fabric, with each new piano note generated after a touch is sensed.

We also plan to use a generative machine learning approach to personalize the musical output based on the user's interaction with the conductive threads and the resulting changes in capacitance. Considering this, the second approach uses Google's Magenta API to develop generative music based on the interface interaction . Magenta's Piano Genie model can be used to create a real-time, intelligent musical instrument that uses AI to generate a variety of sounds as it adapts to different circumstances in the interaction.

As it is a work in progress, we will pursue the development of a deep learning model that generates personalized animations and music according to the user's interaction with the fabric. We hypothesize that combining a music generating deep learning model with our physical fabric interface will offer great potential as a novel musical instrument. Additionally, in future work, we plan to implement gameplay dynamics, with challenges related to rhythm and strength.

5 DISCUSSION AND CONCLUSION

Our goal is to have a functioning prototype set-up and begin evaluating its performance, initially in the lab. Particularly, we will evaluate its ease of access to the user, as well as its ability to adapt to changes in the environment. These evaluations would allow us to construct improvements.

To evaluate the accessibility of our model, we would collect feedback data from multiple, diverse subjects through user survey results and possibly other tests. This allows us to measure how easy the interface is to use and learn and how engaging it is to users. Additionally, conducting the evaluation in different contexts allows us to find similarities and differences between the contexts. These distinctions could potentially provide us with design guidelines that work in multiple settings.

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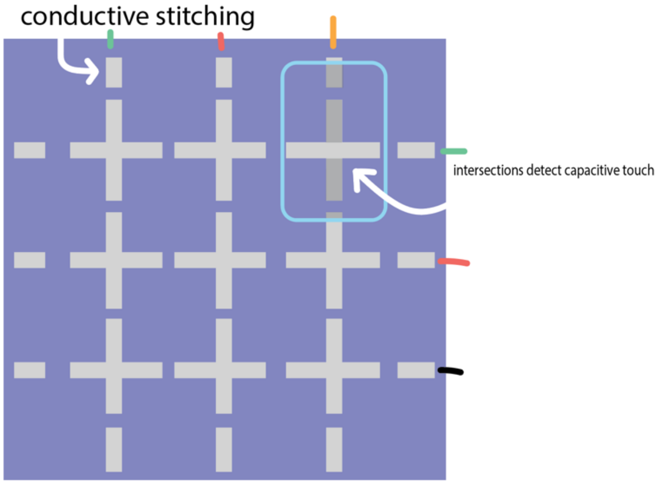

Figure 3: Fabric Pattern Design

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