GestoLumina: Gesture interpreted Light, Sound and Haptics. Towards a Framework for Universal Music Design

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ABSTRACT

Introducing GestoLumina (GeLu), a novel interface by the Universal Music Design (UMD) team at CymaSpace, whose mission is to enhance arts and culture accessibility for the Deaf and Hard of Hearing (DHH). UMD is a program that applies principals taken from the "Universal Design" concept towards music accessibility and inclusion for the DHH. The primary goal of UMD is to create experiential, educational pathways for the DHH to interact with music in a meaningful way. GeLu is the first UMD interface in the framework and is modular in its feature set allowing the user to choose, based on use case, between visual and/or haptic feedback along with gestural sensing. GeLu combines two bracelets: a ring system with gesture sensing and haptic feedback; and an audio-reactive LED color feedback array. The ring system captures tactile input through sensors and provides haptic feedback on the fingertips. The audio-reactive LED color feedback bracelet visualizes audio data, creating dynamic visualizations synchronized with sound.

Author Keywords

Deaf/DHH, inclusion, audio-visualization, haptic, interface

CCS Concepts

•**Applied computing** → **Sound and music computing;** •**Human centered computing** → User centered design; •**Social and professional topics** → *People with disabilities;*

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1. INTRODUCTION

Universal Design is the design of buildings, products or environments to make them accessible, regardless of age, disability or other factors [10]. In contemporary society, music is exclusionary to DHH individuals. Unquestionably, Music has an indelible presence, shaping emotions, culture, and experiences. However, for the DHH, this profound avenue of human expression remains largely inaccessible, creating a disparity in the enjoyment and engagement with auditory stimuli. UMD seeks to investigate the universal properties of music to adopt a universal design towards new interfaces for musical expression for the DHH, by the DHH.

Figure 1: CymaSpace Founder, Myles, GeLu/guitar session

Sound is a part of a DHH individual's world, but, without technology, DHH people are excluded from many sound-based experiences. In his book, 'Sonic Agency,' Brandon Labelle explores "sonic thought and imagination," [7] a theme explicitly relevant to the DHH. UMD advocates for the DHH community's sonic agency by increasing scientific exploration and artistic application of alternative ways to engage with sound and music, while empowering artists and designers to adapt current technologies for increased accessibility and inclusion.

Music not only entertains but also serves as a conduit for emotional resonance, political resistance, and social connection within the hearing-able world, affording one sonic agency. Yet, the concept of 'Sonic Agency' transcends mere auditory perception; it delves into the realm of sensory inclusivity, advocating for the expansion of avenues through which all individuals, regardless of auditory ability, can engage with and experience music's profound impact on the human psyche [1]. In this context, the notion of increased accessibility to music takes on paramount significance for the DHH community. Enabling accessibility extends beyond aurally perceiving the sound to feeling the vibrations; understanding rhythms through touch, and experiencing the emotive power of music through alternative sensory pathways. This forms the crux of our research. We aim to imbue DHH participants with a novel means to tangibly experience the essence of music, thus fostering a more inclusive and vibrant musical landscape.

Similarly, accessibility research reflects an underrepresentation of DHH designers, musicians, composers, and performers as active participants [4]. We address this by constructing collaborations across DHH, Cochlear Implant users, and hearing-able researchers where DHH designers and performers take the forefront. This participatory approach not only increases visibility of DHH researchers but also provides examples for the DHH community who wish to engage in music research and performance [3].

2. RELATED WORK

GeLu takes inspiration and builds directly from [5], while incorporating the authors' backgrounds in complex non-invasive, idiomatic music 3D gesture tracking [15], and ASL gesture recognition [12]. Previous authors explore similar frameworks with myo-electric and nerve sensing gesture recognition techniques [9] [17]. The MiMu gloves[1] sensing framework directly informs GeLu design considerations [11].

3. MOTIVATION

For much of the DHH community, the experience of music has long been a source of curiosity and intrigue, despite its elusive nature. By understanding theory, science and physics, and relevant contextual/cultural information related to sound and music, a DHH individual can understand their environment more intimately. Music holds a profound significance in society, evoking emotions, memories, and connections that transcend language and culture. However, for DHH individuals, the traditional auditory components of music remain largely inaccessible, leaving many to wonder what it might be like to fully engage with this art form.

The impact of music on the hearing-able is undeniable, with its ability to evoke powerful emotions and elicit physical responses. Yet, the sensation of music as vibrations, harmony and rhythmic patterns remains a curious mystery, prompting many within the DHH community to explore alternative avenues for experiencing and interacting with musical content. An example being that DHH individuals often augment their experience with sound by over-amplifying the bass frequencies in the music using subwoofers for the increased haptic feel [2].

One phenomenon that occurs due to lack of early music training is that a DHH individual does not develop equilibrium or proprioception in the same manner as a hearing-able child [16]. One author relates that they potentially cannot ride a bicycle due to this [6]. Our goals are to develop symmetrical, multi-model musical interfaces for the hands [8], as well as incorporate dance[3].

[1]https://www.mimugloves.com/gloves/

Table 1: Cost Breakdown

Light Bracelet	**Price**
Pixelblaze ESP32	39.00
Pixelblaze Sensor Extension Board	29.00
Basswood lasered into living hinges	.50
Duct Tape attached to bottom of living hinges	.05
USB cable	1.00
WS2812B LED Strip (8x 1.5" sections)	1.00
Power Bank	17.00
Total	**87.55**
Haptic Bracelet	**Price**
LILYGO T-Display-S3	21.98
Lithium Polymer Battery 3.7V	9.70
Basswood lasered into chassis	.50
Velcro Strip 3"	.05
USB cable	1.00
MEMs micophone	2.60
L298N Motor Driver	2.5
10mmx3mm Mini Vibration Motors	1.40
MPU6050 3 Axis Accelerometer Gyroscope Module	3.30
DF9-16 FSR	9.12
Total	**52.70**

4. SYSTEM DESCRIPTION

GeLu is a Low-cost (Table 1), open source, easily replicable gesture interface with audio visualization. It features fingertip rings equipped with a single LED diode, haptic feedback mechanisms and force sensor resistors (FSRs). The system is flexible and modular (Figure 1).

4.1 Analog Sensor Input

Functionally, the gesture sensing and haptic portion of GeLu's sensor/haptic control data is transmitted and received via Bluetooth Low Energy (BLE) MIDI technology for wireless networking with compatible devices. GeLu utilizes the MPU6050 Accelerometer for gesture data acquisition. The sensor data is scaled into control data (MIDI). The MPU-6050 accelerometer senses inertial and orientation changes that are converted to wireless MIDI Note/CC messages towards triggering of sounds or modulation of musical parameters. DF9-16 FSRs, on the fingertips, are used to trigger MIDI notes by squeezing the fingertips to the thumb. Tactile feedback from embedded haptic feedback actuators within the rings are driven by selected MIDI note feeds (sender and/or receiver).

[2]https://djmag.com/news/deaf-rave-collective-and-founder-dj-troi-lee-are-subject-new-netflix-documentary
[3]https://www.nytimes.com/2023/08/20/style/haptic-suits-deaf-music.html

4.2 Audio Visualization

The LED array portion of GeLu incorporates the SPW2430 MEMS microphone built into the Pixelblaze ESP32 microcontroller's sensor extension board. That audio input is visualized in real-time on the bracelet LED array programmed to convey the frequency and BPM of audio sources. This visual representation offers users an indication of the music being created (Figure 2).

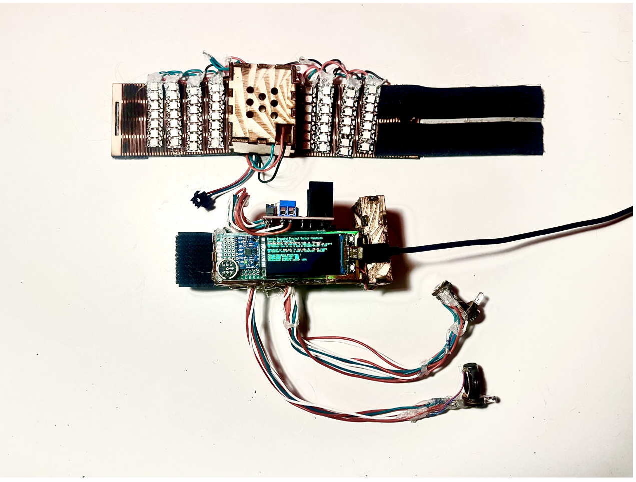

Figure 2: Modular GeLu System [Top: mic input/LED array; Bottom: Rings- sound control/haptic feedback]

4.3 Hardware, Software and Latency

Gelu uses a 3.7V lithium rechargeable battery for power. Average power usage of the ESP32 tech draws about 95-240mA while active. Max activity will last four hours and low activity is closer to 11 hours of charge. This provides the necessary energy for extended use in mobile applications, ensuring portability and flexibility.

Sensing/Haptics: GeLu's sensor/haptic platform is built on the LilyGo T-Display-S3 microcontroller, offering WiFi and Bluetooth capabilities. With a dual-core XTensa LX7 processor running at 240MHz, it ensures efficient processing with low latency. The inclusion of a full-color TFT screen on the T-Display-S3 facilitates rapid prototyping by allowing developers to visualize sensor data in real-time (Figure 3).

Figure 3: full-color TFT screen with realtime sensor readings

This feature streamlines the development process by enabling fine-tuning of values based on observations during use. Additionally, compatibility with the Arduino IDE simplifies programming. Haptic feedback is facilitated by Mikoke 3V ERM vibration motors controlled by an L298N H-bridge. LEDs illuminate when haptic feedback is engaged (Figure 4).

Light: GeLu's audio input processing and lighting control platform is built on the Pixelblaze WiFi LED controller and the Pixelblaze Sensor Extension Board. The ESP32 dual-core processor efficiently controls WS2812B LED strips.

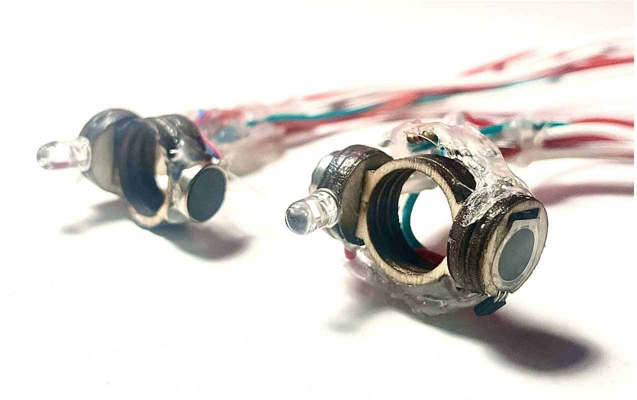

Figure 4: Laser cut rings with FSR, haptic acuator and LED

By processing sensor data locally and using efficient communication protocols, the device achieves low-latency interaction (approx. less than 2.3ms based on testing- LED/haptic feedback, round-trip).

5. ETUDE STUDY

A musical etude study is described with two GeLu users- a Cochlear Implant user (GeLu composer/end user) and a fully Deaf music student (GeLu Lead Design Engineer) in duet performing an experimental musical excerpt.

In Toussaint's book, *"The Geometry of Musical Rhythm"*, rhythms are statistically analyzed as being innately musical vs. chaotic. It's shown, eschewing a cultural lens, that humans adopt specific rhythms worldwide while rejecting others. When viewed in a euclidean sequence the adopted rhythms present a symmetrical shape when connecting the time points [14]. This symmetry isn't visible via a linear step sequencer or notation and we believe there is value in visualizing musical content this way to a DHH musician.

We've chosen a preset group of rhythms that a DHH musician can trust (being an adopted symmetrical and "innate" rhythm) as a platform for pattern building using haptics and light[4]. Using GeLu, a DHH musician performs basic percussive patterns while the other DHH musician receives the sensation of that pattern on one finger. In duet, the second DHH musician can perform back a polyrhythm using another finger. This technique is akin to multi-track recording with headphones, rather with haptics. Meanwhile, by selecting contrasting enough sounds that each DHH musician triggers, both GeLus are able to convey each players' respective pattern, "polyphonically", with an independent color that includes trigger time point, decay over time and BPM information. These experiments are towards the development of a large-scale 3D-spatial, immersive "haptic-acoustic" musical work featuring hybrid DHH/hearing-able musicians, while concurrently informing the development of a DHH Music Curriculum[13].

6. CONCLUSIONS AND FUTURE WORK

GeLu is versatile and compatibile with smartphones and Bluetooth-enabled computers. Prototyping with PureData and Ableton Live has been trivial across OS platforms, underscoring the device's seamless integration into diverse digital music creation setups [GeLu Video Portfolio[5]].

[4]https://amy-alexander.com/pigs

[5]**GeLu demo:** `https://www.youtube.com/playlist?list=PLTDFu1P8i7yb2SjZbE5K3kKBOBn99Y1hs`

We will incorporate American Sign Language (ASL) and DHH art form Visual Vernacular (VV) to create visible/multi-sensory low-frequency haptic vibrations for participants in a way that merges universal musical expression with proprietary DHH forms of visual communication towards a burgeoning novel art form.

Currently, the ergonomics of the fingertip rings present a notable limitation being tailor fit. Future iterations of GeLu could implement a more universally adaptable design ensuring a one-size-fits-all solution, accommodating users with varying finger sizes while maintaining comfort and flexibility without compromising sensing accuracy.

Scaling down the size of the components is possible, reducing the overall footprint. Custom PCBs will streamline assembly and improve connectivity. This integration will reduce clutter, enhancing functionality and portability, making GeLu more efficient, robust and user-friendly. We intend to include haptics inside the bracelet armband to provide multi-channel audio, while additionally exploring newly emerging actuators for high-frequency response.

Porting the framework to the Nano 33 BLE Sense will enhance the project's capabilities with an array of built-in sensors: IMU, microphone, gesture, light, proximity, barometric pressure, temperature, humidity. Integrated Bluetooth functionality simplifies wireless communication with external devices. Compatibility with machine learning applications affords advanced gesture recognition and musical interaction. The Nano 33 BLE Sense's sensor suite and machine learning capabilities will allow us to design a smarter, more efficient platform for DHH music creation and interaction.

Beyond music, we envision GeLu in multiple social use cases: providing "speech-to-text" capabilities for DHH and hearing-able individuals to communicate fluidly in social, work, or institutional settings; or MIR source-separation and recognition for environmental sound level monitoring to become more familiar with the sonic energy of a space. As the work progresses, we plan to conduct user-surveys of GeLu in deployment with members from our regional DHH community in-order to meaningfuly further our user-centered design iterations.

Moreover, there is a growing aspiration within the DHH community to not only experience music but also to actively contribute to its creation. DHH individuals envision a future where they can create music that both DHH and hearing-able individuals can enjoy, that celebrates the unique perspectives and experiences of the DHH community while captivating audiences of all backgrounds. This desire to create an entirely new genre of music, reflects a deep-seated longing for there to be more accessibly in the musical landscape for the DHH [2]. GeLu emerges as a response to this curiosity for a more inclusive musical experience, by providing an open-source, multi-modal platform for experimentation that can be adopted and adapted[6].

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[6] `https://github.com/DillonSimeone/Gestolumina`
[7] `www.universalmusicdesign.org`

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