UniMIDIHub: A Prototype of Accessible Digital Musical Instruments for Musical Inclusion

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Abstract

Accessible digital musical instruments (ADMIs) are a promising approach to music-making, demonstrating that technology can play a transformative role in promoting inclusivity in musical practice. In this paper, the author's industrial Ph.D. project is presented, a prototype of ADMI, developed together with the company *Audio Modeling* and the founder of *Musica Senza Confini.* The prototype was tested in live ensemble performances involving both users with disabilities and professional musicians, yielding encouraging and insightful results regarding its practical applicability and musical integration. This paper contributes to the broader conversation on inclusion in digital music-making and offers a concrete step toward the development of tools that accommodate diversity without compromise.

Keywords

Accessibility, usability, digital music instruments, accessible digital musical instruments, human-computer interaction

1. Introduction

In the field of Human-Computer Interaction (HCI), music plays an important role in its form as a digital instrument, whether it has an interface or not. We can also assert that music plays a crucial role in the interaction between humans and the computer when this union intentionally generates sound. Adding the aspects of accessibility and inclusivity, the field leads directly to accessible digital musical instruments (ADMIs), intended as accessible musical control interfaces used in electronic music, inclusive music practice and music therapy settings[1]. The intersection of HCI and ADMIs presents a critical frontier for inclusive design and creative expression. As digital tools increasingly mediate musical experiences, ensuring accessibility for people with disabilities has become both a technological and an ethical imperative. Traditional music interfaces often assume visual, auditory, or motor capabilities that exclude many potential users from full participation in music creation, education, and appreciation. Recent advances in HCI offer promising avenues for addressing these challenges by reimagining how people interact with music technologies. From gesture-based controllers and adaptive user interfaces to haptic feedback and brain-computer interfaces, novel interaction paradigms are enabling more inclusive access to musical expression. However, designing effective and accessible systems requires a deep understanding of both the diverse needs of users and the advantages of emerging technologies. This paper will present the author's industrial Ph.D. project, a prototype of ADMI, developed together with the company *Audio Modeling*[1] and the founder of *Musica Senza Confini*[2]. Called in its latest version *UniMIDIHub*, it acts as a multilayer ecosystem designed to facilitate MIDI communication on multiple platforms and devices. The remainder of the paper is structured as follows. Section 2 presents an analysis of the scientific literature on the subject, studying it to uncover prevailing trends and recent innovations. Section 3 provides an in-depth look at *UniMIDIHub*, specifying the design principles of the interface and the technical solutions implemented. Section 4 presents the observational studies

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undertaken, detailing the research question, experimental protocol, testing procedures, and outcomes derived from empirical data. Section 5 brings together the findings of the author and outlines the main takeaways from the study.

2. State of the Art

The development of ADMIs has become a central concern in the intersection of music technology and HCI. These systems aim to broaden access to musical expression for individuals with physical or cognitive impairments, and have found applications in inclusive education, music therapy, and performance contexts[2][3]. Early innovations, such as the bioelectric controller by Knapp and Lusted[4], laid the foundation for using alternative input modalities in musical control. More recent work has proposed formal frameworks for evaluating ADMIs, such as the Dimension Space model[3], and has emphasized participatory and inclusive design practices[5][6]. Tangible User Interfaces (TUIs) represent a widely explored category within ADMIs. These systems offer embodied interaction through physical artifacts and have been used to support creativity, education, and rehabilitation. Examples include magnetic-tag interfaces[7], block-based systems like Block Jam[8], and commercial platforms such as the Reactable[9]. Gaze-based interaction has emerged as a powerful alternative for users with severe motor impairments. Systems such as the EyeHarp[10] and Kiroll[11] enable musical control through eye movements. However, these often depend on specialized hardware, posing accessibility challenges in everyday contexts[12]. Additionally, the accessibility of mainstream music software has gained attention. Studies on digital audio workstations (DAWs) have highlighted both progress and ongoing limitations in screen reader support and UI design[13]. Research efforts increasingly recognize the importance of inclusive design, not only for assistive tools but across the broader digital music ecosystem[14]. In summary, ADMIs and related accessible technologies continue to evolve, with research focusing on usability, adaptability, and creative empowerment across diverse user populations.

3. An Inclusive and Accessible Music Software Instument

The project prototype presented in this paper, *UniMIDIHub*, focus of the author's research, is a flexible software application developed to enable MIDI communication across multiple platforms. The concept originated from the founders of *Musica Senza Confini* (a musical initiative aimed at children and adults with psychophysical disabilities, focused on inclusive music making as part of its work on accessible ensemble performance), who was tasked with creating performance strategies for a user with extremely limited mobility, only able to move their fingers, toes, and eyes.

Based on these assumptions, the research question on which the research and subsequent developments were based concerns the possibility that the software project could be aimed at individuals without a specific disability or ability, but rather at everyone, regardless of their ability. In fact, ADMIs dedicated to a specific disability are more common than this approach. To follow this path, the research framework planned to test the software on people with different types of disability, one at a time, and then conduct an initial observational study aimed at people with unique and different characteristics, together. to understand how the software works, as shown in Figure 1, the user is able to play a song with *UniMIDIHub*, reproducing musical chords and sequences through the movement of his eyes, fingers and toes. The system leveraged an eye tracker, routinely used by the user for his daily activities, to let her select colored pads on the screen, while micromuscular sensors triggered control actions mapped to notes, chords, short MIDI sequences, or other sounds. Thanks to its configurable design, *UniMIDIHub* can be adapted to different user needs and offers a broader selection of pieces to play.

The software runs on a central computer, receives input from a variety of devices, and sends MIDI messages to a digital audio work station (DAW) hosted on a separate system. Within the DAW, a multitrack project is loaded and each track can be assigned to a different input device, enabling collaborative and inclusive musical performances.

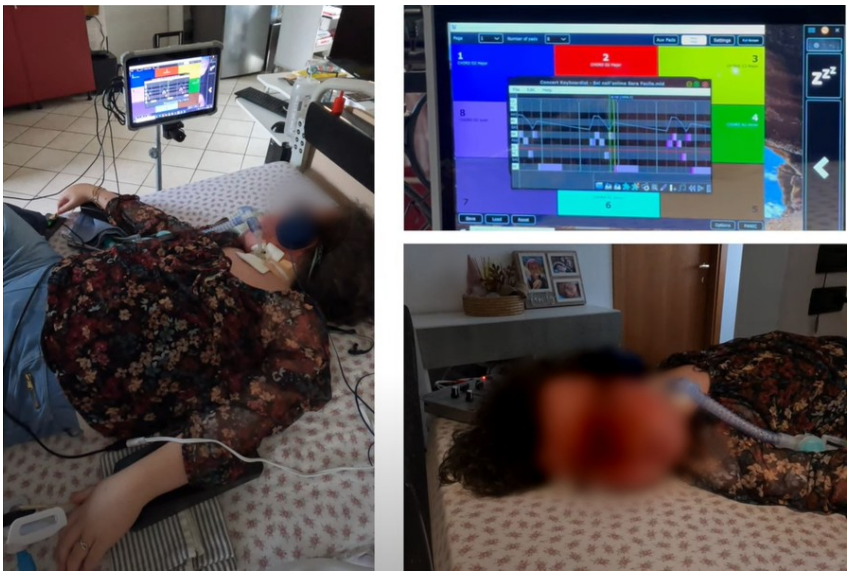

Figure 1: A quadriplegic user uses *UniMIDIHub* through eye movement and the use of micromuscular sensors with fingers and toes.

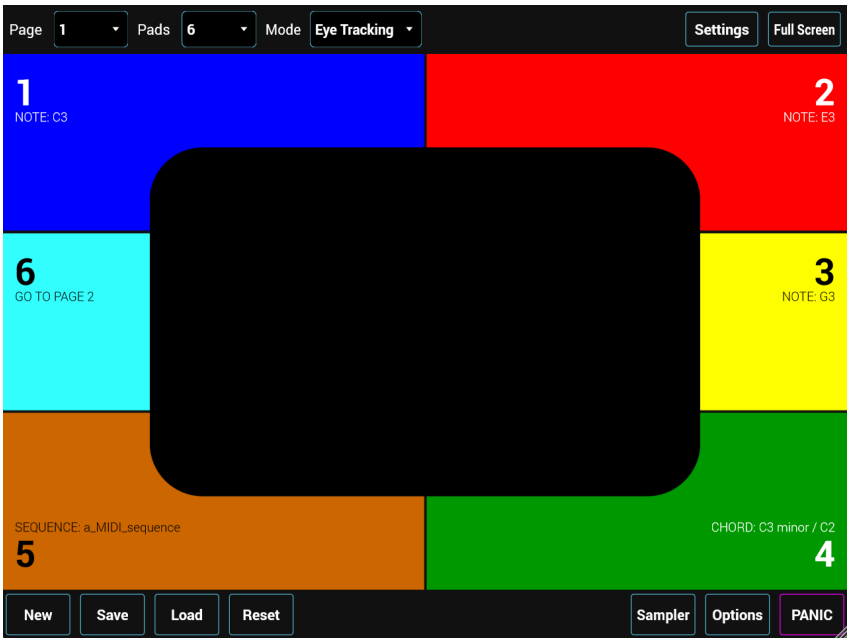

Figure 2: Interface of the latest prototype of *UniMIDIHub*, in the Eye Tracker mode.

UniMIDIHub is developed in C++ through the JUCE framework and is compatible with both macOS and Windows. Consists of a standalone user interface with configurable colored pads, ranging from 2 to 12 per screen (Figure 2), that can be activated through different type of input devices, facilitating accessibility for diverse user needs.

Through the Settings menu, each colored pad can be fully customized with a range of parameters, including:

- Input Type: **Trigger** that activates the sound on mouse hover; **Hold** that activates on hover and deactivates when the cursor exits the area; **Latch**, that toggles the sound on hover, deactivates on the next hover;
- Generated Action: assignable to a MIDI Note, MIDI Control Change, MIDI Chord, MIDI Sequence, a sample, or a navigation command (e.g., page change);

- MIDI settings: channel, note, velocity, release-velocity values, chord properties, and adjustable delay in milliseconds for both MIDI Note-On and Note-Off messages;
- Visuals: custom pads color;
- Input controls: two main keyboard shortcuts and an optional shortcut to repeat the last triggered note;
- Output for the event: MIDI Out, which sends the message to a DAW, to be played, or Sampler, an additional view to set various type of music samples.

In the Setting menu it is also possible to switch between ”Main Pads” (the colored ones) and ”Aux Pads”, which are additional configurable pads that function identically to the main ones but are hidden from the main interface. These pads are triggered exclusively via keyboard shortcuts. In this way, any external device, such as video game controllers, extendable keyboards, accessible devices, etc. that can be mapped with keyboard keys, can “play” *UniMIDIHub*. For every setup, it is possible to save, load, and reset the configuration, with the opportunity to save numerous setups to load at the time of the performance. There are two possible screen views: the ”Eye Tracker” Mode (see Figure 2) which provides a rectangular area with rounded corners in the center of the screen, as a rest area for the gaze and as a transit area from one pad to another non-adjacent one. The ”Touch Screen” Mode which instead shows the pads in the entire screen and allows easier performance with touch devices. One of the standout features of *UniMIDIHub* is its integration with the MIDI protocol. As a universal standard for digital music communication, MIDI allows the software to interface with a wide array of tools, including DAWs, plugin hosts, virtual instruments, and external MIDI hardware, enabling maximum workflow flexibility and compatibility. Due to its cross-platform compatibility, configurable interface, and comprehensive MIDI functionality, *UniMIDIHub* offers a flexible toolset for music interaction. It supports a range of use cases, including sample triggering, virtual instrument performance, and effect manipulation, thereby facilitating diverse approaches to music production and control. The developments achieved so far have led to the release of a first marketable version on Audio Modeling channels. This step is not considered a point of arrival, but rather a starting point for sales to the public. Research and development will continue even beyond my Ph.D.

4. Observational Studies and Results

Two observational studies, informal uses, and musical performances were held with *UniMIDIHub*. The software developments achieved so far have taken into account all the feedback received. The observational studies aimed at evaluating the usability and accessibility of the software prototype. The firs empirical investigation[15] was designed to assess whether users with different physical and sensory abilities, each with varying levels of musical knowledge and technological familiarity, could successfully interact with the system. The study was grounded in a central research question, as anticipated in section 3: Can *UniMIDIHub* be understood and used by individuals regardless of their physical abilities? The underlying hypothesis suggested that the system’s flexible design would accommodate a broad spectrum of users by allowing them to configure the software with the input devices they already know and use in their daily lives. Three individuals participated in the study, each bringing unique profiles that enriched the evaluation process. Primarily they were trained to the purpose of the software, without showing it, allowing the study to observe how intuitively the interface could be understood and used. During the test, participants were asked to complete a series of progressively complex tasks using *UniMIDIHub*. These tasks tested basic interactions, such as play a button, as well as more advanced operations like configuring pads and navigating interface pages. Observations and recordings were used to document each user’s approach, errors, and success rate. After the test, a post-test questionnaire was submitted using both closed (Likert-scale) and open-ended responses to evaluate the user experience from the participants’ perspectives. The first observational study revealed that participants were generally able to complete the assigned tasks, though users with visual impairments encountered notable accessibility challenges, particularly due to limited screen reader support and interface feedback. Post-test feedback reflected a range of user experiences, from high satisfaction

among users with motor impairments to moderate frustration among blind participants. The findings highlight both the adaptability of the *UniMIDIHub* and the need for improvements in visual accessibility, offering guidance for future development toward more inclusive musical interfaces.

A second observational study was conducted to evaluate *UniMIDIHub* following the integration of improvements based on feedback from the initial user study. This iteration involved seven participants, all of whom were students enrolled in a Sound and Music Computing program. The study aimed to investigate the following research question: Can students with a background in music technology understand and operate *UniMIDIHub* independently, and would they propose any additions or modifications to its design? As in the previous study, participants were introduced to the context and purpose of the software but received no prior demonstration or detailed instructions on its use. They were then asked to complete a series of tasks with increasing levels of complexity. The results revealed two primary trends. On one hand, several participants expressed a desire for a more streamlined interface or the inclusion of contextual guidance to enhance usability. On the other hand, despite an initial period of uncertainty, all participants were ultimately able to explore and interact with the software independently. These findings suggest that the application is, in principle, accessible to users with relevant domain knowledge and that its interface can support self-directed exploration, though further refinements may improve the overall user experience. The feedback gathered from this second study has also informed the ongoing development of *UniMIDIHub*. The current version, incorporating these refinements, has subsequently been tested in live ensemble performances involving both users with disabilities and professional musicians, yielding encouraging and insightful results regarding its practical applicability and musical integration.

5. Conclusion

In the field of HCI, accessibility remains one of the primary challenges. For software to be considered truly usable and inclusive, it must be accessible to individuals with a wide range of abilities and disabilities. This concern is particularly significant in the context of digital musical instruments, which, through their transition from analog to digital, have already contributed to lowering several barriers to musical expression. The growing field of ADMIs offers further promise, demonstrating that technology can play a transformative role in promoting inclusivity in musical practice. It is within this framework that the present research project is situated. The aim of *UniMIDIHub* is to broaden the possibilities for musical interaction without fundamentally altering the daily practices of its users. By enabling control through devices and tools that users are already familiar with, the system seeks to support creative expression while minimizing the cognitive and technical load often associated with new technologies. The observational studies carried out, first with individuals with diverse impairments, and later with students in the field of music technology, have provided valuable feedback that continues to shape the development of the system. The results confirm that, despite initial uncertainties, users can navigate and operate the software independently. Furthermore, live ensemble sessions involving both professional musicians and users with disabilities have offered promising insights into the practical effectiveness and musical potential of the system in real-world settings. Looking ahead, this work contributes to the broader conversation on inclusion in digital music-making and offers a concrete step toward the development of tools that accommodate diversity without compromise.

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Declaration on Generative AI

Either:
The author(s) have not employed any Generative AI tools.

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