The Sound Tree Project: Developing Personal and Collective Expression with Accessible Digital Musical Instruments

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Figure 1: The Sound Tree Project

Abstract

The Sound Tree Project investigates how accessible digital musical instruments (ADMIs) can champion both personal and collective musical expression. Through a sustained six-month ethnographic engagement with five performers and two support artists, we explored how to create personalised instruments for a public performance outcome. The technical framework combined multiple wireless motion sensor devices placed inside different objects and the development of a real-time movement-to-sound processing hub within a live coding environment. The performance was centred on an accessible sound sculpture, the *Sound Tree*, where digital instruments coexisted with traditional sound making objects. Drawing from our shared process of experimentation, improvisation, and personalised instrument creation, we present some key 'magic moments' that were woven into the final performance and discuss how they might serve as evidence of personal expression and validation of the design process. The emergence of these moments demonstrate the value of real-time system adaptation in encouraging individual expression, the importance of sustained engagement in developing personalised instruments and having effective strategies for balancing personal and collective music-making.

These insights have implications in developing accessible music technology and broader approaches to designing technologies that support diverse forms of creative collaboration.

Keywords

Interaction, Accessible, Co-design

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1 Introduction

The evolution of accessible digital musical instruments (ADMIs) reflects a broader cultural shift towards inclusive and equitable arts participation [6, 15] Traditional musical instrument design, developed over centuries, sometimes embodies specific cultural assumptions about physical ability, learning methods, and performance practices [11]. Designing ADMIs challenges these historical constraints, recognising that musical expression should not be limited by physical capabilities or conventional learning approaches[25]. Some of the constraints have been highlighted in previous literature such as flexibility [19, 24], physical interface design, and co-design practice [26]. This cultural transformation aligns with wider societal movements advocating for equity in creative expression, acknowledging that diversity in movement and interaction styles enriches rather than diminishes musical experience [1, 3, 5, 12].

Current approaches to accessible instrument design often focus on solving specific challenges in accessibility, such as adapting traditional musical interfaces [16, 17], creating new control mechanisms [7, 21, 23] or falling somewhere in-between [14]. Key concepts such as "adaptability and customization, user participation, iterative prototyping, and interdisciplinary development teams"[8] provides NIME practitioners with a framework to build successful ADMIs . And while existing ADMIs have made strides in supporting individual needs, they typically focus on either solo performance or group interaction, rarely addressing both simultaneously. However, the field has recently begun to shift toward considering larger questions of musical experience, personal expression, and collaborative performance [2, 9, 10]. This shift reflects a deeper understanding that accessible music-making extends beyond physical interaction to encompass questions of artistic voice, creative agency, and collective musical exploration.

Historically, ADMI design approaches often rely on short-term user testing [18] rather than sustained engagement, limiting understanding of how instruments evolve through extended use. This limitation reflects a fundamental challenge in capturing embodied knowledge. Theories of "embodied cognition"[13] demonstrate that performers develop understanding through their bodies over time, a transformation impossible to observe in brief interactions. This process involves "thinking through doing"[13], where knowledge emerges through ongoing physical exploration rather than abstract reasoning.

This longitudinal approach allowed us to observe how performers' capabilities co-evolved with the instruments themselves, creating conditions for developing personalised instruments using their embodied expertise. The "magic moments" that emerged throughout this process served as evaluation points revealing the instrument's success through observable patterns of engagement rather than verbal feedback, suggesting that sustained engagement is not merely methodological preference but epistemological necessity for understanding ADMIs.

There is limited research examining how immediate system modification capabilities, particularly through live-coding approaches, can support the ongoing development of personalised instruments while maintaining group coherence. This gap in research is especially notable given the increasing availability of flexible programming environments and the need for ADMIs that can evolve alongside performers' developing capabilities and creative goals.

2 Background

The Sound Tree Project brought together five performers and two support artists from a 'community-based arts organisation committed to developing the lives of people of all abilities through arts-based courses.'[1] The group already had existing relationships as part of a shared interest in exploring music through motion. Within in a collaborative co-design environment, together with the the first author in the roles of researcher and instrument designer, the group built upon several established elements:

- The AirSticks [22]: an established DMI turn ADMI motion sensing system developed at Monash Univesity's SensiLab.
- *SuperCollider*:[2] a live-coding environment enabling conversational programming.
- *The Sound Tree*: an accessible sound sculpture previously developed by the group and professional musician Matt Stonehouse.[3]

This existing foundation of tools, space, and community provided an exciting starting point for exploring personal and collective musical expression. The project's path was shaped by a clear performance outcome, with the group working together over a six-month ethnographic engagement, accumulating over 40 hours of direct performer observation and interaction. The research embraced a collaborative, co-design environment where technology and performance practice evolved together. The technical tools centred around a Raspberry Pi 5 hub processing movement data from multiple AirSticks, each transmitting gesture data over WIFI using OSC. The hub supported network connections and ran a *SuperCollider* live-coding environment, supporting conversational programming with real-time motion to sound generation. Documentation and development proceeded in parallel, with video recordings and motion data capture providing detailed information for analysis and refinement of mappings.

Regular workshops, initially twice a month and later weekly, culminated in a public performance at a leading cultural arts venue, providing a clear creative goal for the group. Each workshop was structured while allowing space for organic development of both individual and collective performance practices. This sustained engagement enabled a deep investigation of how personalised instruments can emerge through collaboration, exploring the relationship between technology and human creative expression.

[1] https://yourdna.com.au/
[2] https://supercollider.github.io/
[3] https://mattstonehouse.com/home

3 Technical Framework

The technical framework developed for the project consisted of three components: the AirStick controllers, a central processing hub, and a flexible programming environment for sound generation and control. The AirStick is built around an ESP32 microcontroller and BNO086 IMU sensor, providing wireless real-time interaction using the OSC protocol. The compact size of the AirSticks inspired exploration in tangible instrument design, as they could be easily integrated into different materials while maintaining reliable data transmission. A full technical overview is beyond the scope of this paper, but a more comprehensible technical overview of the AirSticks can be found here [22]. Raspberry Pi 5 serves as the system's central hub, transforming data between performers' gestures and sound generation. This hub processes four AirSticks simultaneously, supporting group performance and individual expressive control. Three hubs and a total of twelve Airsticks were used for the final performance.

Figure 2: The AirSticks and Raspberry PI Hub.

As previously mentioned, the programming environment uses *SuperCollider*, utilising its powerful JIT/REPL environment that enables live coding during workshops and performance development. A key innovation in the software design was the use of reloading individual 'personality' files that encapsulated everything needed for an interactive sound instrument:

- Synthesis definitions : uniquely designed synthesis using audio units designed with numerous input parameters including direct access to IMU data.
- Mapping relationships : a variety of strategies for mappings used in numerous combinations including :

  - Preprocessing - Applying dead zones, thresholds, and noise reduction
  - Response shaping - using non-linear curves to shape and refine mappings
  - Range adaptation - Scaling to performer-specific calibrated ranges
  - Temporal processing - Adding smoothing, acceleration detection, and historical context
  - Musical mapping - Converting processed values to musically relevant parameters
- Control behaviors : inputs also included from the system itself, other instruments (community) to change the behaviour of the instrument
- Event handling logic : logic and state management were easy to develop, edit and design for each unique event

Importantly, this dynamic code could be modified and reloaded during workshops with each 'personality' connected to a shared 'community' data structure that maintained musical parameters between instruments, such as tempo, root notes, and energy. This dual approach enabled both individual expression and collective coherence. An AirStick device could be used as a solo instrument or part of a larger instrument involving several devices.

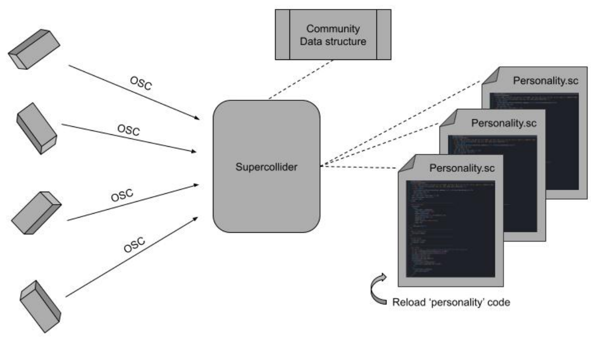

Figure 3: The framework used within Supercollider

The instrument definitions proved particularly powerful as an inspiring creative playground for real-time adaptation, as all aspects of the interface could be modified simultaneously. This use of conversational programming brought code into the creative space, providing a dynamic and responsive technical framework in which to work.

Additionally, the framework included a custom documentation tool, notably OSCCam, which embeds OSC data into video streams using repurposed metadata tags. The integration of movement data with video recording provided a process for analysing and refining gesture mappings, while also serving as an inspiration to composition and sound design.

4 Development Process

4.1 Workshops

The workshops were conducted with all performers, including the researcher, working together in the rehearsal space — playing, exploring, and discovering new ways to create music through motion. This approach blurred traditional boundaries between researcher, performer, and technology developer, creating a space where everyone's contributions shaped the evolution of both instruments and performance practice.

The workshop series began with exercises centred around drawing, talking and listening, where sounds served as creative prompts for artistic expression and group discussion. Performers offered their own sound selections to a shared playlist, establishing a sonic environment that encouraged associative ideas.

Figure 4: Workshop drawings made by the performers.

Next, an AirStick was introduced with a few basic mappings to play along with the curated playlist. The performers took turns wearing or holding the device, performing small improvisations and exploring how they might want to make music through motion. The basic mappings were adjusted in real-time, responding directly to the performers gestures, energy levels and verbal feedback. Objects and materials were then presented, offering different possibilities of adapting the AirSticks.

The process of improvisation, tuning mappings, and experimenting with adaptation continued throughout the project, each session building upon the previous one. A typical workshop would begin with performers revisiting established mappings to warm up, build confidence and familiarity. New sound ideas were gradually introduced and gestures offered by everyone, with each addition shaped by close observation of engagement and evolving needs. Over the course of the project, the group worked on developing personal ADMIs, ensemble dynamics, and individual adaptation strategies.

Documentation played an important role in the development process, using OSCCam to capture both video and motion data of performers' gestures. This technical documentation was complemented by regular meetings with support artists, where creative ideas and planning were shared and refined. The use of performers' own recordings — including vocalisations and acoustic instruments — as source material for the digital instruments further strengthened the ownership of the instruments.

The process was characterised by several key elements:

- Iterative refinement of mappings based on performer feedback and observed interactions.
- Integration of personal sound materials connecting performers' experiences.
- Regular iteration between technical development and creative exploration.
- Flexible workshops to accommodate emerging interests, discoveries and needs.
- Collaborative decision-making about performance development.

The development process was both structured enough to maintain forward momentum and flexible enough to respond to emerging possibilities and the needs of everyone in the room.

4.2 Rehearsals

The goal of a public performance inspired the group to use narrative elements to structure the different modes of making music we developed. As a group, a narrative was devised to support many of the different ADMIs discovered in the workshops. The workshops became rehearsals, with performers having ownership over their particular ADMIs, performing solos, duets and ensemble pieces. This extended period of engagement provided time for participants to not only develop their personal instruments but also to rehearse and ultimately perform with them.

4.3 Performance

Completing the process was a final performance, providing an opportunity to share with the wider community; a celebration of this collaborative process in creating diverse sound movement expressions. The performance showcased how personal relationships with digital instruments could extend beyond individual expression to create rich, collaborative musical experiences. The diversity of interaction styles — from direct physical sharing of instruments to subtle musical responses between performers — demonstrated the flexibility of the system in supporting various forms of collective creativity.

5 Development Practice

5.1 Physical Integration

The physical integration of the AirSticks encompassed two distinct approaches: direct body attachment through wristbands, and integration of physical objects, where the AirSticks were embedded within various materials—balls, fabric, and suspended strings—creating tangible instruments. These two approaches revealed significant differences with distinct mapping strategies and performance practices. Body-worn wristbands focused attention directly on the performers' natural movement patterns and physical expression. This approach highlighted personal movement patterns, with the instrument becoming an extension of the performer's bodily expression. Performers who chose this configuration developed mappings that responded directly to their individual movement styles.

Object-based integration utilised simple but effective mounting solutions - velcro, tape, and elastic bands - to embed the AirSticks within various materials. The physical properties of the materials themselves became part of the instrument, as the size, flexibility, texture and form of the materials suggested movement patterns and inspired different possibilities for sound-gesture mappings. Objects included:

- soft foam objects attached to strings
- embedding within fabric
- soft fluffy ball
- attachment to various found objects.

This flexible approach to physical integration, body attachment and object-based exploration, enhanced the ability to adapt to individual preferences and performance styles. The simplicity of developing diverse physical interfaces encouraged rapid prototyping and experimentation, allowing performers to quickly test different ways of integrating the AirSticks and find the approach that best suited their expressive goals.

Figure 5: Objects and materials used for adapting AirSticks.

5.2 Object-Sound Narratives

The integration of AirSticks into various physical objects provided inspiration and a narrative framework that helped shape how performers developed their musical expression, with the physical properties of materials naturally suggesting both movement possibilities and sonic characteristics.

5.3 Emergent Narratives

The affordances of these sound objects suggested both movement qualities and sonic characteristics:

- Soft foam object on string, evoked animal pet-like characteristics that influenced both their sound design and how performers interacted with them.
- Fabric pieces, encouraged flowing arm gestures that mapped to synthesized wind sounds, creating an environmental narrative.
- A fluffy ball with laughing samples invited a shared playful interaction.
- Sticks, long elastic bands and sheets were all experimented with and some used in moments of the performance.
- A mixture between acoustic and electronic sound-making, suggesting new ways of thinking about instrumental relationships.

5.4 Physical-Digital Integration

The relationship between physical objects and sound design emerged as a crucial element in creating meaningful musical experiences, particularly through the integration with the *Sound Tree*. This hybrid sculpture of hanging acoustic and digital instruments created a rich context for narrative development and musical exploration. The use of the *Sound Tree's* structure created multiple layers of interaction — ADMIs hung alongside traditional sound-making objects, creating a unified performance environment. The physical arrangement encouraged exploration of both acoustic and digital sound possibilities. The tree structure itself became part of the narrative framework, suggesting narrative elements.

6 Expression in Practice

6.1 Individual Expression

Through the workshop process, 'magic moments' of individual expression emerged as performers developed deep personal relationships with their instruments. They reflect performer agency, in their choice of expressive movements for making sound, whether it was expansive energy, micro-movement or voice and movement integration. These moments illustrate how the adaptive nature of the system encouraged different approaches to musical expression, each emerging from the intersection of personal movement preferences, sound design, and creative exploration. We observed how these instruments became "natural extensions"[4] of performers, with magic moments marking key points in this process.

These moments serve as crucial evaluation points that go beyond the limitations of traditional assessment methods like post-hoc verbal feedback, that may not support diverse communication styles. Through observing physical transformations in movement quality, emotional connections between each other and expressions of joy or sustained focus, it became clear that meaningful evaluation would be through highlighting these moments. Drawing on the theories of "embodied cognition" [13] and "situated understanding"[20], we recognise that physical engagement reveals cognitive and creative processes that may not be accessible through verbal reflection.

These magic moments also showed how the combination of ADMIs and a sustained engagement enabled the emergence of highly individual performance practices. Each performer not only developed unique performances but also discovered personal narratives that gave meaning to their interactions with the instruments. The diversity of approaches — from high-energy exploration to small-gesture control to voice-movement integration — demonstrates the system's flexibility in supporting varied forms of musical expression.

6.1.1 Magic Moment 1: Expansive Energy. One performer enjoyed high-energy interaction possibilities, developing an instrument that responded to bold, expansive movements with equally dynamic sonic results. The mapping design featured multiple parameters controlling timbre and rhythms, creating rich, varied sounds that changed with each activation.

This performer's engagement was characterised by:

- exploration of maximum intensity and range of movement
- visible excitement and laughter during discovery
- continuous pushing of the instrument's dynamic limits.

This magic moment demonstrated how immediate, responsive feedback supported the development of virtuosic control within a personal highly energetic performance style.

6.1.2 Magic Moment 2: Micro-Movement Mastery. Another performer developed an instrument that magnified subtle gestures, particularly focusing on wrist movements. Embedding the ADMI inside blue fabric was also used to accentuate the gesture suggesting a number of possible sound narratives. This instrument required a different perspective and mapping implementation:

- Heightened sensitivity to small changes in movement.
- Careful calibration of response curves.
- Alternative approach to generating sound events.

The resulting instrument demonstrated how the system could adapt to support highly controlled, intimate forms of expression.

6.1.3 Magic Moment 3: Voice-Movement Integration. An innovative approach emerged through two performer's integration of voice, recorded samples, and movement. The duo created a dynamic performance piece using:

- recorded personal vocalisations of a chicken and a frog were integrated as sound samples
- physical embodiment of the animals - being a chicken and a frog - during the performance, providing movement inspiration
- live vocalisations, in response to the ADMI samples, were part of performance
- the combination created a playful, multi-layered improvisation.

This magic moment illustrated how personal sound materials and movement can be a great source of inspiration for creative performance narratives. The use of voice recordings, combined with physical gestures and live vocalisation, demonstrated how the system could support complex relationships between movement, recorded sound, and live performance elements.

Figure 6: *The Sound Tree*

6.2 Collective Expression

The technical framework encouraged musical interactions between different groupings of performers to develop a collective performance practice. The collection of duos, trios and group ensemble relationships were found in existing social connections and through spontaneous improvisations. The use of a shared playlist of sound landscapes and music supported the development process as different performance approaches and individual instruments developed. The networked ADMIs were incrementally introduced, allowing time for each combination to explore and refine the orchestration and collective performance.

The group performances often formed around shared musical narratives, particularly in the creation of environmental soundscapes. Performers' individual instruments became associated with elements of the collective soundscape — flowing fabric movements controlling wind-like textures, rolling balls creating rainfall effects, and sudden gestures with rigid objects generating thunderous accents. This approach allowed individual expression while building a sonic relationship between different performers' contributions.

6.2.1 Magic Moment 4: The Storm Approaching. The group would often begin each rehearsal discussing the weather and the effects it had on nature, the trees, pets, birds and insects. The sounds of rain, wind, and creatures were introduced into the curated playlist and then used as atmosphere when improvising with the AirSticks. These controllable sounds of nature were then replaced with real-time synthesis, giving parameter control over rain (density), wind (density, pitch), and thunder (multilayered samples). These sounds were then matched with performers and gestures they developed using the narrative of a storm approaching. Collectively, the performers worked together, orchestrating a sound collage piece.

6.2.2 Magic Moment 5: The Finale. In one notable example, a percussionist's dominant hand movements triggered baseline patterns, while two other performers shared a ball that controlled melodic elements, its modulation responding to the baseline. Simultaneously, performers working with fabric created atmospheric layers - one generating high wind-like textures, another producing bell-like arpeggios. These multi-layered performances demonstrated how personalised instruments could work together in creating complex musical structures. Devices could function as independent musical interfaces in an ensemble or multiple devices operate as a single unified instrument, with each device personalised while contributing equally to the overall performance. The technical capacity to connect with multiple devices was crucial in exploring these types of collective performance practice. The framework evolved to support:

- musical parameters like key and tempo shared across "personality" files
- mappings to remain tuned to its specific performer's movement style
- sound relationships developed that fostered both solo and group playing.

7 Discussion

This research demonstrates several significant implications for both the design of ADMIs and broader approaches to inclusive creative practice. Through the integration of adaptive technology, collaborative development, and physical interaction design, the project reveals new possibilities for assisting diverse forms of musical expression while maintaining meaningful group interaction.

The effectiveness of the technical adaptive interface, particularly its implementation through live-coding, suggests important directions for future ADMI development. These technologies offer unprecedented flexibility in mapping movement to sound, allowing real-time adaptation of instrument behavior to individual needs and preferences. The success of the 'personality' file structure, encapsulating all aspects of the instrument, suggests a model for future systems that could include LLM's generating mappings and sonic ideas at the request of a performer.

The project's sustained ethnographic engagement and co-design process has implications for how we approach the development of accessible music technology. The evolution of individual and collective practice over the six-month period demonstrates the value of extended engagement in allowing deep relationships to develop between performers and their instruments. This suggests that the development of truly accessible instruments requires not just technical iteration but also sustained development of how personal and collective musical practices emerge over time.

The integration of physical objects and materials proved to be a powerful strategy, offering alternative modes of interfacing with a digital instrument. The ease with which performers could access the affordances of a range of physical objects or materials, created opportunities to develop a personal connection while suggesting a performance narrative. This implies that future ADMI design might benefit from considering physical interaction design not just as a technical challenge but as an opportunity for narrative development and personal connection.

8 Conclusion

The project ultimately demonstrates how technology can assist diverse forms of movement-based expression, focusing both on individual needs and collective creative practice, creating new possibilities for accessible music-making. These findings have implications not only for ADMI design but for broader questions of how to create technologies that champion diverse forms of creative expression while fostering meaningful collaborative experiences.

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10 Ethical Standards

This project was conducted with the necessary ethical consent and permissions through Monash University.

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