MICRO and MACRO - Developing New Accessible Musicking Technologies

Mari Lesteberg, Alexander Refsum Jensenius
RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion
Department of Musicology, University of Oslo
Oslo, Norway
{mariles,alexanje}@uio.no

ABSTRACT

This paper describes the development of two musical instrument prototypes developed to explore how non-haptic music technologies can be accessed from a web browser and how they can offer accessibility for people with low fine motor skills. Two approaches to browser-based motion capture were developed and tested during an iterative design process. This was followed by observational studies of two user groups: one with low fine motor skills and one with normal motor skills. Contrary to our expectations, we found that avoiding the use of buttons and mice did not make the apps more accessible for the participants with low fine motor skills. Furthermore, motion speed was considered more important for people with low motor skills than the size of the control action. The most important finding is that browser-based musical instruments using sensor-based and video-based motion tracking are not only feasible but allow for reaching much larger groups of people than previously possible. This may ultimately lead to both more personalized and accessible musical experiences.

CCS CONCEPTS

• **Human-centered computing** → *Accessibility technologies*; **Interaction design**; **Sound-based input / output**.

KEYWORDS

Browser-based instruments, Web audio, Accessibility, Motion capture, JavaScript

ACM Reference Format:
Mari Lesteberg, Alexander Refsum Jensenius. 2022. MICRO and MACRO - Developing New Accessible Musicking Technologies. In *AudioMostly 2022 (AM '22), September 6–9, 2022, St. Pölten, Austria.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3561212.3561231

1 INTRODUCTION

Most musical instruments demand precise and fast fine motor control and require thousands of hours of practice to master [20]. But what about people who have conditions that cause reduced fine motor skills? Is it possible to create musically exciting instruments that can be played using only gross motor skills?

AM '22, September 6–9, 2022, St. Pölten, Austria

ACM ISBN 978-1-4503-9701-8/22/09.
https://doi.org/10.1145/3561212.3561231

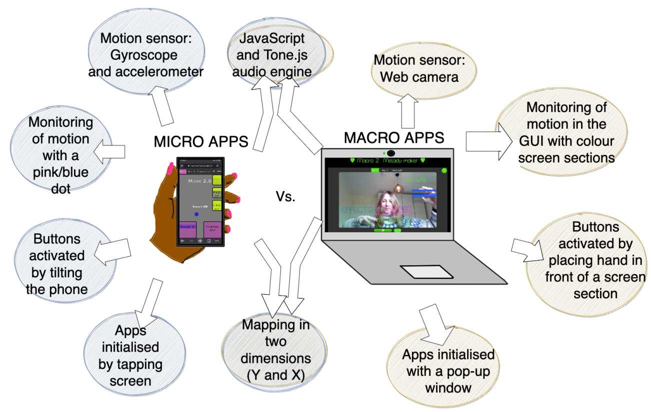

Figure 1: An overview of the interaction possibilities of the developed Micro and Macro apps.

In this paper, we report on a study of how it is possible to design and implement accessible *musicking technologies* that can be controlled with motion in the air. We call them musicking technologies to underline that we do not aim at making traditional *musical* instruments for fine-level sound production and modification. Instead, we look for ways of creating interfaces that allow for active explorations of sound and music [18]. Hence, extending Small's concept of musicking [26] to instrumental design seems logical.

In this study, we decided to focus on accessibility for people with low fine motor skills. Conditions that affect muscles, such as Cerebral Palsy and Parkinson's Disease, affect the motor ability and can make it difficult to play many kinds of traditional musical instruments [1] [2]. This study's primary focus has been prototyping. However, we ran a small observational study where three people with a muscle condition that affect fine motor ability participated. In addition, three people with normal motor ability participated.

The paper starts with an overview of accessible musical instruments before presenting and discussing the development of the two prototypes: Micro and Macro. An evaluation of the prototypes will follow, and finally, we will briefly explain the observational study that followed the development process.

2 ACCESSIBLE MUSICAL INSTRUMENTS

In an extensive review from 2019, Frid included 113 publications covering 83 accessible musical instruments [14]. In this study, Frid found that the tangible approach has been the most common in accessible musical instrument design. She also found that few instruments have feedback modalities beyond sound, and only a few have vibrotactile feedback. This is not only a limitation of accessible musical instruments; many researchers in the new interfaces for musical expression (NIME) community have explored new ways of creating feedback in their interfaces over the years [12], and musical haptics, in particular, has gained traction recently [13].

The prototypes we present in this paper attempt to increase the contribution of non-tangible musical interaction in the context of accessibility. Two examples of non-tangible instruments designed to be inclusive to people with physical disabilities are Soundbeam and Motion Composer. They are both based on tracking motion in the air; Motion Composer uses computer vision for motion tracking [9], while Soundbeam uses ultrasonic sensors for distance tracking [7]. Both systems are used in music therapy, and Soundbeam mainly targets children with learning difficulties [3].

Both Soundbeam and Motion Composer are commercial products with price tags that fit the budgets of institutions rather than individuals. Thus, most people do not have access to such instruments. Hence, we have been interested in developing non-tangible instruments accessible both in functionality and availability.

The Macro and Micro prototypes presented in this paper are inspired by previous studies of air performance [25] [11] [21] [23], and the development of air performance instruments [22] [17]. This line of works shows strong, albeit complex, relationships between musical sound features and bodily position and motion that can be exploited in musical instrument design.

3 DEVELOPING THE MACRO AND MICRO PROTOTYPES

Both the Macro and Micro apps were developed in JavaScript, a well-known language for web-app development. Nowadays, developing interactive music systems in JavaScript is relatively easy using the Web Audio API [6] and Tone.js [5] frameworks. This approach makes it possible to reach out to many people online, which would be more challenging if we had developed in more common audio programming environments, such as PD or Max [8]. We wanted to create apps easily accessible to people with little or no experience with music-making.

Covid restrictions prevented us from carrying out the user testing we had initially planned. Fortunately, thanks to the web-based development solution, it was possible to continuously receive comments through feedback forms built into the apps. This allowed us to employ an iterative and user-centred design approach [16]. We started with the design and development phases, followed by testing and evaluation. Our reflections on testing and the feedback received then looped back into new design iterations. In the following, we will first present the design of the video-based Macro app before moving on to the sensor-based Micro app.

3.1 The evolution of the Macro app

The idea behind the Macro app was to explore the use of large-scale motion tracking using the built-in camera on a laptop. This was achieved using the Diff Cam Engine, an open-source project that enables motion detection in JavaScript [10]. The Diff Cam engine works by subtracting subsequent frames in a video stream and calculating the quantity of motion as the sum of active pixels.

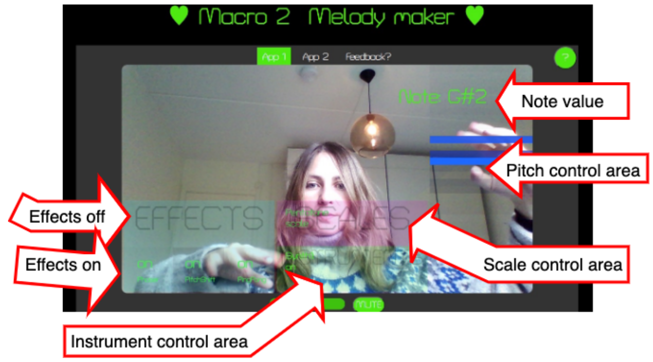

Figure 2: The interface of Macro 2.0 App 1, a Theremin-like instrument played in the web browser on a laptop.

To ensure decent video quality and be adaptable to different screen sizes, we opted for an image resolution of 900 x 500 pixels. To ensure as low latency as possible, we set the update rate to 10 frames to capture all available frames from the camera. The tracking was done in a low-resolution grid. Different screen parts were divided into areas mapped with other functionalities and separated with different colours.

3.1.1 Macro 1.0. By integrating instruments and effects from the Tone.js library, we explored more complex sounds and timbres than the pure sine and saw tone oscillators used in the first test versions. This led to the launch of the first official version, released with a built-in feedback form for users to report back. This version was called Macro 1.0, named after the longest/largest spatiotemporal levels of human action [17]. Macro 1.0 included three versions: App 1, App 2, and App 3.[1] They were all based on web camera motion detection but had different approaches for musical interaction. Video1.mp4 demonstrates Macro 1.0.

3.1.2 Macro 2.0. With the second release, the system was taken a step further by introducing a button-free design. The intention was to make the instrument more accessible by avoiding fine motor skill-dependent actions like clicking a button with a mouse. Macro 2.0 App 1 (Figure 2) is a Theremin-like musical instrument where you can control pitch on the Y-axis (vertical) and select between two effects and two instruments on the X-axis (horizontal). The Macro 2.0 App 2 was a random music generator where users could interact by turning instruments on and off and controlling effects. This was inspired by the web-app Synastheasia [4] and the interaction concept of the Self-playing Guitars [15].

3.1.3 Macro 2.1. The last iteration of the Macro app, version 2.1, tried to address the various feedback from test users of version 2.0. This included improving the instructions, tweaking the interaction settings, and adjusting the visual appearance of the apps. It also resulted in the removal of some features. Several users complained that they had problems with unintentional sound output. They were performing in the air with video-based tracking, allowing sound to be continuously produced. This might be exciting in some ways but challenging from the perspective of a musical instrument, especially

[1] https://fractionmari.github.io/macro/

since there was no apparent visual reference. In the Macro app, any kind of motion that was picked up by the web camera would change the sound. It was possible to avoid the problem by moving in and out of the frame, as demonstrated in Video2.mp4.

A similar approach was used to control the music generator in Macro 2.1 App 2. As demonstrated in Video3.mp4, the system allowed for switching "buttons" on and off with hand gestures. However, the system was still susceptible to picking up unintended motion. A certain level of control could however be achieved after some hours of practice. Macro 2.1 app 2 could, for instance, be used with other instruments as a backing track for musical improvisation, as demonstrated in Video3.mp4.

Even though it is possible to work around the problem of continuous control in the current instruments, as demonstrated above, it will be interesting to explore gesture-based interaction in future systems. The most straightforward approach would probably be to apply spatiotemporal thresholding to the continuous motion data.

3.2 The evolution of the Micro apps

The Micro apps[2] were inspired by the concept of *sonic microinteraction*, using motion on the boundary to standstill for sonic control [17]. The idea was to develop "air instruments" based on data from smartphones' accelerometers and gyroscope sensors. As for the Macro apps, development was done with JavaScript, and the Web Audio API [6].

Another central concept of the Micro apps is the use of *inverted mapping*, which was introduced with The Sverm project [19]. In the Sverm instrument, micro-motion was explored together with inverted mapping, which means that the sound volume would decrease when the participants accelerated their movements. To make any sound at all, the participants had to be as still as possible.

3.2.1 Micro 1.0. The first release of the Micro apps included three different apps with different approaches for exploring sound and music. Video4.mp4 demonstrates the three apps from the initial release. The concept of inverted mapping was explored most in this app version and was given less focus in the later versions.

3.2.2 Micro 2.0 and Micro 2.1. Like the transition from Macro 1.0 to 2.0, we wanted to remove the buttons and make the instrument touch-free when transitioning from Micro 1.0 to 2.0. This was achieved by implementing a way to make the user "hover" the buttons with a blue dot that monitored the phone's motion.

In this way, the user could control melodies and musical parameters by tilting the phone and activating buttons by tilting the phone in different angles. However, it was impossible to make the app entirely touch-free, as the accelerometer and gyroscope sensors have to be activated by a touch action, e.g. by tapping the screen. As the functionality of tapping the screen already was there, we decided that a secondary function could be implemented with this action. Tapping the screen in Micro 2.0 and 2.1 app 1 will change the synth instrument (Video5.mp4).

In Micro 2.0 app 2, the same random groove generator as in Macro 2.0 app 2 was introduced. The newer release adapts to the operating system by converting the accelerometer values. In Micro 2.1 app 1, the only visual change was that the name of the scale

[2]https://fractionmari.github.io/micro/

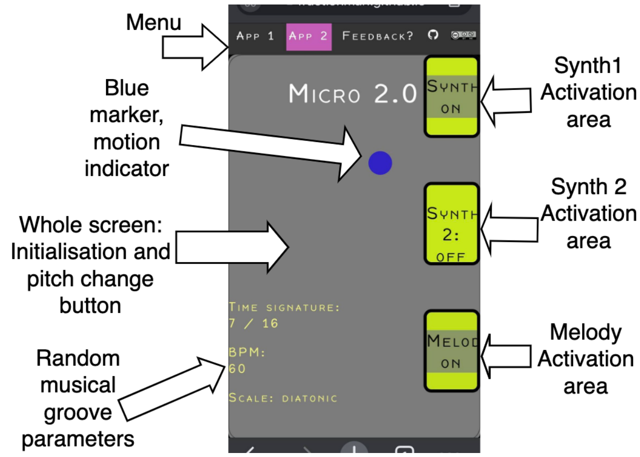

Figure 3: Micro 2.0 App 2: Random generator

("pentatonic", "whole-tone") appears instead of just "scale 1" and "scale 2". In Micro 2.1 app 2, the transpose value is displayed when the user tilts the phone up and down.

Instead of transposing the melodic groove for only three seconds as in Micro 2.0 app 2, the transposition effect is permanent and will not change before the user taps the screen again (Video6.mp4).

4 EVALUATION

4.1 Feedback forms

The apps were distributed to users through our student and employee network at the University of Oslo and social media. A simple web form was integrated into the app. The feedback form was open-ended since our main goal was quickly to capture people's immediate impressions.

We received in total 48 answers distributed on the four app iterations. The feedback was on technical issues (such as the lack of sound or crackling sound) and conceptual issues (comments on relationships between action and sound). There was a good distribution of praise and criticism.

The comments were used to improve the subsequent iterations. For example, several Micro 2.0 app users reported that had to tilt the phone in a position that made it difficult to reach the activation area. This was due to the flipping of the iPhone's accelerometer values versus Android and Windows phones. Due to the iterative development cycle, this issue was fixed for the next iteration.

4.2 Observational study

Three people with a health condition that causes low fine motor skills and three people with normal motor skills were invited to try out the apps in an observational study.

The studies showed that the users with low fine motor skills and people with average motor skills could interact with the prototypes on almost the same level. Both groups used the various sound and music features available in the apps. However, both groups encountered problems with the Macro apps creating unintended sound due to the continuous sensing described above. This could be solved by teaching the users how to move in and out of the frame. A better solution may be to implement a proper action or gesture-based tracking system in the future.

The informants with low fine motor skills generally reported less enjoyment of the apps than those with average motor skills. The Micro 2.1 app 1 received (slightly) best ratings among users and was most favourably described in the interviews. Given the low number of users included in the study, we should be careful about generalizing too much from these findings.

A starting point for our development was to investigate how non-tangible interaction would work for people with low fine motor control. Of the three users in the observational study, only one said that tilting the phone to activate buttons was easier than clicking a button on the mobile screen. The two others said they were used to touch and mouse technology and found this easier than moving in the air.

The users with low fine motor control said that the *size* of the motion space was less important than the *speed* with which they had to move. It would be interesting to explore different spatial, temporal, and spatiotemporal settings and how they influence the interaction in future iterations.

5 CONCLUSIONS

The main focus of this project was to design and implement accessible musicking technologies that could be controlled with motion in the air. We successfully developed two prototype instruments, Macro and Micro, in which we explored two interaction types (through video-based and sensor-based tracking) and two types of musical control (pitch control versus music control).

It is more cumbersome to develop software instruments using web technologies rather than specialized music interaction paradigms (such as PD or Max). However, the benefits include easy online deployment and a potentially much larger user base. The development of online motion tracking musicking technologies might be valuable for future research and artistic experience. Our case also facilitated a truly iterative and user-centred design approach. Involving users from early on helped shape the development and the result.

We only included three users with low fine motor control in the observational study. Still, it was beneficial to observe their interaction with the apps and to hear their comments on what worked well and not. They seemed to like the idea of moving in the air, however, having some button-based control, in addition, might have simplified the interaction.

Our exploration thus far has shown that we have a long way to go to make genuinely accessible musical instruments. There are few examples of such instruments, and there is not much literature on what works or not. We believe that this is an exciting line of research that may not only be important for people with low fine motor control. Developing more accessible musicking technologies at large could benefit everyone.

ACKNOWLEDGMENTS

This research is partially funded by the Research Council of Norway through the MICRO project (250698) and RITMO (262762O).

REFERENCES

[1] MSD Manual 2021. *Cerebral Palsy (CP) Syndromes.* MSD Manual. https://www.msdmanuals.com/professional/pediatrics/neurologic-disorders-in-children/cerebral-palsy-cp-syndromes

[2] MSD Manual 2022. *Parkinson Disease.* MSD Manual. https://www.msdmanuals.com/professional/neurologic-disorders/movement-and-cerebellar-disorders/parkinson-disease

[3] Soundbeam n. d.. *How is Soundbeam Used.* Soundbeam. Retrieved 08.05.2022 from https://www.soundbeam.co.uk/how-is-soundbeam-used

[4] Synaesthesia n. d.. *Synaesthesia.* Synaesthesia. https://wheelibin.github.io/synaesthesia/

[5] Tone.js n. d.. *Tone.js.* Tone.js. Retrieved 18.08.2021 from https://tonejs.github.io/

[6] Web Audio API n. d.. *Web Audio API - Web APIs | MDN.* Web Audio API. Retrieved 01.09.2021 from https://developer.mozilla.org/en-US/docs/Web/API/Web_Audio_API

[7] Soundbeam n. d.. *What is Soundbeam.* Soundbeam. Retrieved 08.05.2022 from https://www.soundbeam.co.uk/what-is-soundbeam-1

[8] A. R. Jensenius & S. Saue A. Xambó, R. Støckert. 2020. learning to code through web audio: a team-based learning approach. *journal of the audio engineering society* 68, 10 (october 2020), 727–737. https://doi.org/10.17743/jaes.2020.0019

[9] A. Bergsland and R. Wechsler. 2016. Turning movement into music: Issues and applications of the MotionComposer, a therapeutic device for persons with different abilities.. In *SoundEffects-An Interdisciplinary Journal of Sound and Sound Experience, 6(1).* 23–47.

[10] W. Boyd. 2016. *Motion Detection with JavaScript.* https://codersblock.com/blog/motion-detection-with-javascript/

[11] J. Fuhrer C. Martin J. Tørresen & A. R. Jensenius C. Erdem, Q. Lan. 2020. Towards Playing in the 'Air': Modeling Motion–Sound Energy Relationships in Electric Guitar Performance Using Deep Neural Networks. In *Proceedings of the Sound and Music Computing Conference.*

[12] A. R. Jensenius & M. J. Lyons (Eds.). 2017. *A NIME Reader: Fifteen Years of New Interfaces.* Springer, Berlin.

[13] S. Papetti & C. Saitis (Eds.). 2018. *Musical Haptics.* Springer International Publishing, Cham, Switzerland. https://doi.org/10.1007/978-3-319-58316-7

[14] E. Frid. 2019. Accessible Digital Musical Instruments— A Review of Musical Interfaces in Inclusive Music Practice. In *Multimodal Technologies and Interaction.*

[15] Victor Evaristo González Sánchez, Charles Patrick Martin, Agata Zelechowska, Kari Anne Vadstensvik Bjerkestrand, Victoria Johnson, and Alexander Refsum Jensenius. 2018. Bela-Based Augmented Acoustic Guitars for Sonic Microinteraction. In *Proceedings of the International Conference on New Interfaces for Musical Expression.* Virginia Tech, Blacksburg, VI, 324–327.

[16] Y. Rogers & J. Preece H. Sharp. 2015. *Interaction Design: Beyond Human-computer Interaction* (4th ed.). Wiley.

[17] A. R. Jensenius. 2017. Sonic Microinteraction in "the air". In *The Routledge companion to embodied music interaction*, & M. Leman M. Lesaffre, P.-J. Maes (Ed.). Routledge, New York, 429–437.

[18] A. R. Jensenius. 2022. *Sound Actions: Conceptualizing Musical Instruments.* The MIT Press, Cambridge, MA.

[19] A. R. Jensenius and K. A.Bjerkestrand. 2012. Exploring Micromovements with Motion Capture and Sonification. In *Arts and Technology.* Springer, 100–107.

[20] A. Kozbelt & A. M. Williams K. A. Ericsson, R. R. Hoffman. 2018. *The Cambridge Handbook of Expertise and Expert Performance.* Cambridge University Press.

[21] J. Torresen & A. R. Jensenius K. Nymoen, R. I. Godøy. 2012. A Statistical Approach to Analyzing Sound Tracings.. In *Speech, Sound and Music Processing: Embracing Research in India*, R. Kronland-Martinet K. Jensen & S. Mohanty S. Ystad, M. Aramaki (Ed.). Springer, 120–145.

[22] M. R. Haugen & A. R. Jensenius K. Nymoen. 2015. MuMYO - Evaluating and Exploring the MYO Armband for Musical Interaction. In *Proceedings of the International Conference on New Interfaces For Musical Expression.* Baton Rouge, LA.

[23] T. Kelkar and A. R. Jensenius. 2018. Analyzing Free-Hand Sound-Tracings of Melodic Phrases. *Applied Sciences* 8, 1 (2018). https://doi.org/10.3390/app8010135

[24] Mari Lesteberg. 2021. *Micro and Macro: Developing New Accessible Musicking Technologies.* Master's thesis. University of Oslo.

[25] & A. R. Jensenius R. I. Godøy, E. Haga. 2006. Playing "Air Instruments": Mimicry of Sound-Producing Gestures by Novices and Experts. In *Gesture in Human-Computer Interaction and Simulation.* 256–267.

[26] C. Small. 1998. *Musicking: The Meanings of Performing and Listening.* University Press of New England, Hanover.

A APPENDIX

Videos demonstrating concepts presented in the article can be found here: https://doi.org/10.5281/zenodo.6862114. More details about the project can be found in the first author's master's thesis [24].