Exploring Diverse Forms of Bareëmins: A Multifaceted Study on Painted Panels and Sculptures as The Site of Performance, Instruments, and Scores

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ABSTRACT
This paper delves into the realm of NIMES called Bareëmins, a distinctive adaptation of the theremin implemented on the Arduino platform, featuring artistically crafted capacitive antennae. Drawing inspiration from the original theremin and the extensive instrument collection of Leon Theremin, Bareëmins represent a fusion of artistic expression and technological innovation. The study explores the transition from traditional theremins, commonly recreated in music programming classes, to the visually engaging Bareëmin family. In this evolution, the conventional antennae are replaced by creatively envisioned antennae, becoming a defining feature across varied shapes and sizes, categorized into handheld, environmental, and painted score species.

Rooted in the artist's synesthetic perception, where sight and sound converge, Bareëmins embody diegetic shapes and colors. The antennae, made from conductive paint, copper tape, or found materials, showcase a commitment to sustainability and inclusivity. The paper provides instructions for crafting Bareëmins using readily available materials, fostering an environmentally conscious approach. By enhancing the artistic appeal and making the construction accessible, Bareëmins bridge the gap between visual artistry and musicality, offering a unique and inclusive avenue for exploring the intersection of art and technology in the realm of musical instrument design.

Author Keywords
NIME, proceedings, handmade, hardware, accessible

CCS Concepts
• **Hardware** • **Human-centered computing** → **Accessibility**; Accessibility theory, concepts and paradigms; • **Applied Computing** → **Arts and humanitie**s; *Media arts*;

1. INTRODUCTION
A Bareëmin, embodies a unique adaptation of the theremin crafted on the Arduino platform featuring an artistically constructed capacitive antenna. The Arduino runs a customized sketch, incorporating the CapSense Library by Paul Badger. The antennae of the original theremin was also a capacitive sensor; this aspect of the design explores the original affordances of one of the first electronic instruments.[1]

In many music programming classes students recreate a theremin in Arduino with pitch and volume controlled by a light sensor. This project is so popular it got incorporated into the official Arduino Starter Kit in 2012.[2] In the Bareëmin family this light sensor is replaced by various artistically envisioned antenna. These visually and physically engaging antennae are the defining feature of these NIMEs. Running the same software, the Bareëmin family can be generally categorized into three species: handheld, environmental, and painted score. This project is directly inspired by the original theremin, but also draws inspiration from the extensive array of instruments crafted by Leon Thermen throughout his lifetime.

As a trained artist, I access musicality through visual media; my creative work bridges the boundary between eye and ear. Mirroring that, the shapes and colors of the Bareëmin are diegetic. The antennae can be made of conductive paint combined with non-conductive paint, copper tape, found metal, or any other conductive material in the environment.

Common mark-making supplies, and Earth pigments distinct from charcoal or graphite, can serve as effective "resist" elements in the visual score/antennae, expanding the range of available materials. These practices underscore the commitment to making Bareëmins not only innovative and expressive but also environmentally conscious and widely accessible.

The conductive paint formula exists as a high-end manufactured item, but can be made cost effectively from common materials found at the supermarket and art store. Bareëmins take an eco-conscious approach by recycling charcoal to produce carbon paint. However, irony lies in the sustainability challenge faced in regions where open-fire cooking is not prevalent, (and charcoal needs to be industrially manufactured) highlighting the need for adaptable practices. The instructions for making a Bareëmin found in this paper were designed with a mindful eye towards utilising commonplace household items such as charcoal and acacia powder.

You can see the instructions here
https://www.yuditskaya.com/music/nimey/#instructions

2. ARDUINO IMPLEMENTATION WITH MINIMAL PERIPHERAL SETUP
Bareëmins, effectively translate the craft processes commonly found in arts classrooms into the realm of technological artistry. The introductory-level programming combined with the incorporation of large, physical, visually impactful antennae exemplifies a fusion of simplicity and innovative craftsmanship. This design approach aligns with the “microcontrollers as material” paradigm.[3] The synergy between the Arduino platform and its C code, leveraging off-the-shelf components, underscores the accessibility and user-friendly nature of the Bareëmin's design. This amalgamation of artistic sensibilities with technological simplicity not only facilitates ease of use for creators but also opens up new avenues for artistic exploration and expression.

The Arduino C code for the Bareëmins can be found here https://github.com/timeFliesWhenYoureHavingFun/Baremin

At 38 lines (including comments) and one library, the code is simple, and therefore a good object for analysis in theoretical discussion or educational context. The use of a general purpose library makes it a good example for an introduction to p-comp (physical computing) class covering the general structure of code bases and development environments. Beyond the Arduionos, the hardware needed are two resistors, a speaker, and some conductive material to make the antenna. The sound production mechanism of Bareëmins relies on a 2" 8-ohm 5W speaker, seamlessly integrated with the Arduino platform without the need for additional amplification. This direct connection to a PWM out pin and ground streamlines the instrument's setup. Making Bareëmins is a low-cost, low-effort, high-yield project.

There is an intentional aesthetic embedding of scores within the instrument, forging a captivating fusion of notation, aesthetics, and the instrument's form.

"Reading" the antennae as scores is one method of interacting with the instrument. The various shapes of the antennae and materials leverage different performance affordances for each iteration. Complexity arises from the interplay of simple materials and simple software.

3. THE BAREËMIN IS BUILDING ON THE THEREMIN

Theremins were made in sculptural, and instrument form factors; the instrument form is the classic two-antennae theremin. The sculptural or environment form was called the terpsitone. The terpsitone was a platform for a dancer/performer to activate via movement. The dancer's movements were picked up by multiple antennae placed in and around the platform.[4]

No Bareëmin has a secondary antenna for volume, volume is manipulated at the mixer level or with a guitar pedal. Only one antenna is present is because multiple Bareëmins can be combined, either multiple full antennae on one brain or multiple Bareëmin units can be combined through their antennae, or multiple brains can be attached to one antennae. Likewise the players whose bodies affect the electromagnetic fields of the antennae can combine by touching each other.

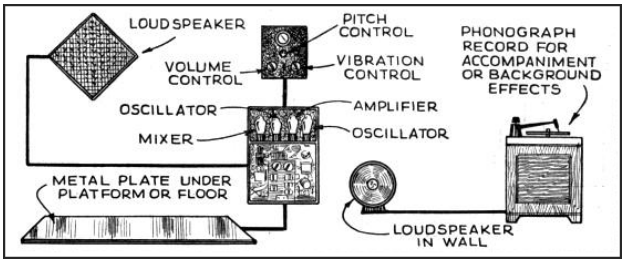

Figure. 1. The components of the system, including the phono. Unit which is used for background effects. From Mason, C. P. "Theremin "Terpsitone" A New Electronic Novelty" *Radio Craft*, volume 8, number 5, 1936

3.1 Sculptural Bareëmins

Crystal Bareëmins introduce a novel dimension to musical performance, featuring a meticulously folded paper crystal adorned with a painted grid on the inside, while the exterior remains unaltered paper. This unique design empowers performers to manipulate the electromagnetic field of the instrument without the need for direct physical or visual contact with the antenna material. In the realm of creative expression, my band, EM KVLT, consisting of Meg Schedel, Jess Rowland and myself, draws inspiration from the summoning of the Electromagnetic Goddess in every performance. The Crystal Bareëmin, with its distinctive form, provides a captivating opportunity to embed antenna within an object, offering a tangible and immersive experience for both musicians and the audience. This creative endeavor takes inspiration from the use of crystals in contemporary new-age altars, adding a spiritual and symbolic layer to the artistic process. Beyond our project, paper crafts like Crystal Bareëmins have gained popularity among makers for home use and boast a rich history in classroom education. Notably, these creations find a home in maker and tech art spaces,[7] aligning with the innovative works of artists like Hannah Perner Wilson and others who have explored the unique intersection of craftsmanship and technology.

The adaptability of Bareëmins to unconventional surfaces expands the possibilities for artistic and engineering exploration and underscores the instrument's capacity to be infused creatively by various facets of our material world. This exploration into diverse surfaces not only enriches the visual and tactile dimensions of the artworks but also showcases the potential for innovative expression through a spectrum of forms, which in turn determines the modes of interaction that can be engaged by a Bareëmin performer.

To see a variety of surfaces explored go here and scroll down https://www.yuditskaya.com/music/nimey/#sculls

To read about gold leaf Bareêmins and learn about the paint making process please go here https://www.yuditskaya.com/music/nimey/#goldLeaf

3.2 Environmental Bareëmins

An entire sculpture can be wired up, or made out of metal and attached to the Arduino-Bareëmin brain to make it a receptive antenna that surrounds the human body within. These structures are made in the fashion of Thermin's terpsitone instrument. Their structure is the same as sculptural Bareëmins, but scaled up in size such that the performer is located inside the piece, rather than holding and manipulating the structure in their hands in order to play it.

There is only one terpsitone left in existence, and not too many projects that are recreations or that build on the project. One notable project is "A Dance in Tune" – an audio kinetic performance for a modified terpsitone and light sensor arrays. With movement by Lina Lauruvėnaitė terpsitone, light sensors, lights and sounds by Adomas Palekas. https://m.youtube.com/watch?v=3eUygQQsNZM

Projects like this are important to keep developing the technological philosophy of the analog environmental instrument. In today's surveillance technostate many spaces are wired up to record, react, and collect data on the movements and behaviours of human bodies with sensors, but few consider the technological substrate as a structural building material that

provides instant biofeedback without quantifying and reporting the bodies inside it to an outside database. As a sonification, Environmental Bareëmins, the terpsitone, and instruments of that nature hold a valuable place in the ecosystem of technologically-based biofeedback spaces and environmental musical instruments.

3.3 Painted Bareëmins: Illustrations and Conductive Artistry

The Painted Score Bareëmin, a unique innovation within this collection, showcases the versatility of conductive paint in both visual representation and functional connectivity. This groundbreaking approach allows the conductive paint used for the Bareëmin antenna to serve dual roles: guiding the musician through a visual score while simultaneously acting as the physical link in the instrument's circuitry, responsible for turning it on and off. The integration of paint introduces a realm of artistic possibilities, enabling the incorporation of various painterly techniques such as mixing, outlining, and experimenting with acrylics, gouache, pens, inks, markers, and other mixed media materials.

The non-conductive painted areas play a crucial role in defining sections of the score, marking physical pauses, and housing essential information commonly found in written and pictographic communication. This integration of conductive and non-conductive areas forms a unique symbiosis, transforming the visual score into a written score and an integral part of the instrument's functionality, influencing both its sound and operation.

There are various adjacent concepts to embedded scores. For example the tangible scores of Enriqué Thomas,[8] or the software embedded score of Hans Christoph Steiner.[9] The difference between the Bareëmin embedded scores and the above examples is that in the Bareëmin case, the scores are an electro-mechanical part of the instrument that makes hardware connections to play the sound. In this sense they are perhaps closest to Hans Christoph Steiner's embedded software score in that as the piece progresses the score is triggering the systems within the composition that make the sound. Painted Bareëmin scores contain symbolic communication in the tradition of visual scores. The non-conductive sections of the score may indicate movement, duration, etc as instructions.

EM KVLT's latest project is playing graphic scores that function as instruments, and simultaneously embedding these scores within acoustic stringed instruments. Our current practice is inspired by circuit diagrams as scores such as Gordon Mumma's Mesa and Max Neuhaus's Max-Feed and Christina Kubisch's Electrical Walks. Our performances are distinct from Enrique Tomás' inherent scores where it is the performer's role to reveal instances of the musical work inherently integrated in the circuitry [10]. They are closer to the idea of a composed instrument where the performer's role [is] to reveal instances of the musical work inherently integrated in the circuitry [11]. We are revealing not only instances of the musical work integrated into the circuity, we are also revealing the acoustics of a space through the combination of microphones, speakers and instruments. We perform the inherent choreography of space and playing the score embedded within.

These score/paintings balance the affordances of score, instrument, and object in a single device. In our performance we use three separate Arduino systems with a stack of conductive paintings. The paintings then activate the circuitry, somewhat like the Shawn Greenlee's Augur system where he uses the "conversion of previously composed graphics as instructions for sound synthesis."[13] However, here the paintings themselves activate the circuitry, while the page serves as a graphic score. Multiple Arduinos can be connected to a single page, or a single performer can connect multiple pages with a series of wires. Complicating matters, we also use acoustic string instruments, such as pianos, harpsichords, harps, and kotos, as both sounding sources and effects units by attaching alligator clips to the metal strings. Each of the Arduino systems has a small speaker, and each performer has a small wireless microphone that sends an amplified signal to larger speakers.

To view recordings of EM KVLT using Bareêmins go here https://www.yuditskaya.com/music/nimey/#EMKVLT

To read about Copper Tape Bareêmin extension go here https://www.yuditskaya.com/music/nimey/#copperTape

Figure. 2. The DodecaOTTO in Tamlab Linz augmented with copper tape by the Feminist Hacking Class of 2023-2024 taught by Meg Schedel, Jess Rowland, and Sofy Yuditskaya.

4. USE OF THE BAREËMIN FORM FACTOR IN EDUCATION

The simplicity of the design allows for instruction at any level ranging from a painting project only, where students create a painted antenna and use shared Bareëmins to hook up to their antennae; to a full programming and soldering workshop with the Arduino to a sculpture project working with conductive metal and welding. This scalability makes the Bareëmins a versatile STEAM project.

Bareëmin making has been taught as a mixed graduate and undergraduate workshop at the Indian Institute of Science, a conference workshop at Harvard, and an independent arts workshop at Walkin Studios.

In educational settings, where considerations of messiness or complexity might arise, the straightforward application of copper tape provides a pragmatic solution, ensuring an accessible and streamlined crafting experience for students. The mixed graduate and undergraduate workshop included painting only, using graphite paint we created multiple visual scores in a zine format, effectively creating a small scorebook that becomes part of the instrument. In this workshop we focused on the musicality of the forms and the documentation of the creative process. The conference workshop at Harvard focused on soldering, understanding hardware, and looking at the scores from a materials studies perspective. The workshop for artists at Walkin Studios cursorily walked through the hardware and focused on making novel shapes and forms with the scores/antenna ranging from 2D - 3D.

Table 1. An anonymized survey of workshop participants follows below. This survey is using a Lickert scale with 5 being the most true and 1 being the least true. The statements are ranked in order from most to least true overall. Five participants' scores are averaged:

I understand how an object can be a computational interface, a score and an instrument	5.0
I found making a score easy	4.8
I found augmenting the instrument with found items and tape compelling and straightforward	4.8
I found the play instructions easy to follow	4.8
I found the instrument easy to use/intuitive	4.8
I found the assembly process easy to follow	4.6
I found the interaction consistent/reliable	4.4
I enjoyed exploring the parameter space of this instrument	4.2
I found the interaction delightful	3.4

5. CONCLUSION

There is some precedent of instruments that accept embedded scores, instruments from the dawn of the electronic music era such as the Variophone, and newer pieces such as those by Thomas and Steiner. Bareëmins push the paradigm in that the score becomes an embedded part of the instrument's circuitry, whilst the antennae are interchangeable. Bareëmins add the concept of embedded score in a hardware-based instrument to ideas of tangible scores, software-based embedded scores, and scores of others.

6. FUTURE DIRECTIONS

Future explorations will involve interconnected networks of instruments such as in the recent "Feminist Hacking" workshop lead by myself and Meg Schedel at Tamlab Linz, where we adapted the OTTOsonics platform as the Bareëmin antenna, and weaved painted, and tape scores into it, as well as other instruments such as a Moog Mini Theremin, and Vlad Kramer's Soma Synth. Since all these instruments share behaviours in common it is possible to weave them together into a greater network of various sniffers that interact with each other in conductive, capacitive, and transmissive ways, creating a space for the human form to play within.

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