

Ripple: Turning Finger Movement into Expressive Music for Accessible, Embodied Music-Making

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Abstract—We present *Ripple*, a low-cost finger-worn exoskeleton that turns small, voluntary hand movements into real-time, expressive music. *Ripple* is built for people whose hand mobility makes conventional instruments inaccessible—older adults in memory care, residents recovering motor function, and others for whom “playing music” is otherwise out of reach. Rather than treating music-making as note-correct reproduction, *Ripple* treats it as an *embodied, expressive act*: continuous finger motion maps to sustained, dynamically shaped sound, so that even minimal movement produces something that feels intentional and musical. Concretely, *Ripple* is a DexUMI-inspired [4], 3D-printed (TPU) finger-worn exoskeleton instrumented with per-finger rotary encoders. As the wearer bends a finger, the encoders stream joint motion over serial to a free, browser-based synthesis engine—built on the Web Serial and Web Audio APIs—that needs no installation, account, or specialized equipment, so a caregiver with a laptop and the device can run a full session. Each finger drives its own sustained, dynamically shaped voice, with selectable timbres and a procedurally synthesized drum kit, while a per-user calibration and hysteresis thresholds ensure that small, effortful movements register as deliberate musical gestures rather than noise. To date, *Ripple* has reached 200+ users across 10+ senior centers, nursing homes, and youth programs in the US, China, and Canada, and we reflect on what real-world use taught us about expressivity, agency, and how to evaluate creative robotic systems beyond task-success metrics. Beyond its human-facing use, the same exoskeleton doubles as a teleoperation interface for a dexterous robot hand in simulation, sketching a path from accessible *human* music-making toward *robot*-performed music driven by human expressive gesture.

I. INTRODUCTION

Most accessible-music tools [1] optimize for *triggering the right note*: press a large button, get a correct pitch. This framing quietly discards what makes music expressive—timing, dynamics, gesture, and the sense that the sound is *yours*. For populations with limited hand mobility, the cost of this tradeoff is high: the activity becomes a task to complete rather than an experience to inhabit.

We argue that accessible music-making is fundamentally an *embodied, expressive control* problem, placing it squarely within this workshop’s scope. The design question is not “how do we let someone hit a note” but “how do we let a small, effortful movement become an expressive musical gesture” [3]. *Ripple* is our attempt to answer that question with a deployable system, and to test it where it matters—in the hands of real users, repeatedly, over time.

II. THE RIPPLE SYSTEM

Sensing exoskeleton. *Ripple* uses a finger-worn exoskeleton (derived from the DexUMI platform [4]) with per-finger rotary encoders, 3D-printed in flexible TPU so it conforms gently

to a range of hand sizes and grip strengths. Encoder readings stream over USB serial. The mechanical design prioritizes ease of donning and forgiving fit over precision capture, because the target users are not roboticists.

Browser-based audio engine. Rather than a custom application, *Ripple* runs entirely in the browser via the Web Serial and Web Audio APIs, hosted as a free single-page app (ripplemusic.org). This is a deliberate access decision: a caregiver with a laptop and the device can run a full session with no installation, accounts, or proprietary software. Each finger drives a sustained oscillator that begins on a detected press and fades on release, with selectable timbres (e.g., soft/bell/pad voices and a procedurally synthesized drum kit). Pentatonic-friendly presets make “wrong notes” nearly impossible, lowering the barrier to a satisfying first experience.

Movement-to-expression mapping. The core of *Ripple* is the mapping from noisy, low-amplitude finger motion to expressive output. A two-phase normalized calibration adapts to each user’s range of motion, and hysteresis thresholds (separate on/off bounds) suppress jitter so that intent, not tremor, drives the sound. A low-effort mode further widens the forgiving band for users with very limited mobility. These choices are not incidental—they are where most of the system’s design effort went, because they determine whether a small movement reads as a deliberate musical gesture or as noise.

Ripple as a teleoperation interface. The same sensing exoskeleton can also pilot a dexterous robot hand. We built a MuJoCo teleoperation pipeline that parses *Ripple*’s encoder stream (via the DexUMI encoder layer), maps the exoskeleton’s finger-joint readings onto the actuated degrees of freedom of a ~ 20 -DoF Wuji Hand through a coupling function, and adds 6-DoF wrist control, so that a human wearer can drive the dexterous hand in simulation in real time. We emphasize that we have **not** yet implemented robot music performance; rather, because the wearer’s finger motion already carries musical intent in the human-facing setting, this interface is deliberately positioned as a route toward robot-performed music—for example, teleoperating the simulated hand to play a virtual keyboard. The point is architectural: one device supports both *human* expression and *robot* dexterous control from the same gesture stream.

III. DEPLOYMENT AND OBSERVATIONS

Ripple has been deployed in recurring, on-site sessions across 10+ senior centers, nursing homes, and youth programs in three countries (US, China, Canada), reaching 200+ users,

including ongoing use at a memory-care facility—a population for which music-based engagement is well documented as beneficial [2]. To make the system sustainable beyond researcher visits, we wrote bilingual (English/Chinese) manuals so staff can run sessions independently.

Across sites, engagement was broad and often immediate. Users with limited or no speech, and those with hearing impairments, were among the most enthusiastic—in large part because the web app communicates the instrument’s state *visually* (per-finger color feedback and on-screen response), so a user does not need to hear instructions or speak in order to understand what their movement is doing. After only a short introduction, many users began improvising their own rhythms and simple tunes, and several performed recognizable melodies despite significant physical limitations and speech differences. The expressive act, in other words, survived the loss of the very channels—speech, hearing, fine motor precision—that conventional instruments and interfaces typically depend on.

At nursing homes, voluntary play averaged roughly ten minutes of self-directed practice per person, suggesting sustained engagement rather than brief novelty. Clinicians on site saw clear potential in the device and asked to keep Ripple at their facility for continued use—an indication of perceived value beyond a single demonstration.

Much of this reach comes down to a deliberately minimal setup. The only calibration each user needs is a single gesture: the wearer relaxes, extends the fingers and palm, then closes them, and the system records the per-finger encoder range and normalizes it for that individual. This one step adapts Ripple to each person’s range of motion, which is what allows the same device to serve users across such a wide range of abilities.

IV. DISCUSSION & FUTURE WORK

The next immediate step is in the hardware. Ripple’s exoskeleton is currently passive—it senses finger motion but cannot move on its own. Adding actuation would let the exoskeleton **move the user’s fingers in response to musical cues**, gently guiding the hand through a melody or rhythm rather than only following it. Ripple would then not just capture a user’s movement but actively help shape it, supporting both music learning and hand rehabilitation.

Our first open question is one the workshop names directly: **how should we measure expressive outcomes?** If the goal is a sense of agency and expression rather than a correct sequence of notes, then accuracy is the wrong thing to score. But we lack simple, reliable ways to tell how expressive or engaged a user felt—especially for users with limited mobility, who cannot easily complete long surveys. We think the field needs lightweight, human-aligned measures of expressive engagement.

A second question is the tradeoff between **forgiveness and expressivity**. The features that make Ripple easy to use—smoothing, pentatonic presets, and generous thresholds—also limit how much fine control a more capable user can reach. A more forgiving instrument is a less nuanced one. Finding the

right balance, and deciding whether it should adapt to each user, is an open design question.

A third question comes from the teleoperation interface: **can a person’s musical gesture drive a dexterous robot performer?** Ripple already reads intentional finger motion to make music. Sending that same motion to a robot hand would turn the system from one that *helps a human play* into one that *makes a robot play*. Building this—a robot hand at a keyboard, first teleoperated and eventually autonomous—would run into the core robotics challenges of timing, dynamics, and contact, but with one difference: the expressive goal would come directly from a human. We have not built it yet, but we see human-gesture-driven control as a promising direction for embodied music.

V. CONCLUSION

Ripple shows that accessible music-making can be an embodied, expressive act rather than a matter of hitting the right notes. With a low-cost, DexUMI-inspired exoskeleton and a free, browser-based audio engine, it has brought real-time, self-directed music to 200+ users across senior centers, nursing homes, and youth programs in three countries—including people whose mobility, speech, or hearing puts conventional instruments out of reach. Coupling the same device to a dexterous robot hand in simulation extends Ripple’s focus from helping people make music to robots that perform it. A motorized, guiding exoskeleton and human-gesture-driven robot performance are our next steps toward making expressive music more widely accessible. Above all, we hope Ripple can make the joy of *creating* music—not just listening to it—accessible to anyone, regardless of age, ability, or experience.

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