

Deploying an AI Music Performance System on a Smart Mandolin

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Abstract—This paper presents the design and development of *MandaLOERIC*, a smart mandolin embedding a rule-based artificial intelligence system for live performance in Irish Traditional Dance Music called *LOERIC*. *LOERIC* currently requires a complex setup involving multiple hardware components, a laptop, and an expert operator, which causes logistic overhead and limits the system’s integration into traditional music practice. We investigate to what extent embedding the system within a Smart Musical Instrument (SMI) can help us address these challenges. *MandaLOERIC* is a self-contained instrument that integrates embedded computing, sensing, audio input/output, and network connectivity. The mandolin hosts *LOERIC* on a compact embedded device, incorporates onboard microphones and audio output, and minimizes external dependencies, thereby reducing setup time and physical encumbrance. Through a preliminary practice-based evaluation, we reflect on our design choices and discuss how these could affect the deployment of the instrument in traditional contexts. We identify possible improvements for the current system and consider on how embedding AI music systems in SMIs could ease engagement with practitioners and provide a platform for future embodied creative explorations.

Index Terms—Smart Musical Instruments, Embedded Computing, AI for Live Music Performance

I. INTRODUCTION

LOERIC is a rule-based artificial intelligence performance system developed through practice-based research [1], [2]. The system performs Irish Traditional Dance Music (ITM) introducing idiosyncratic ornamentation, timing, dynamics, and accompaniment, responding in real-time to a human musician through the acoustic amplitude of their performance and MIDI control messages. Its extensive configurability through JSON files facilitates the creation of different interactions for specific performance contexts through long-format workshops featuring expert musicians [3]. At the time of writing, *LOERIC* has been used in several performances, playing both in duet

and in ensembles featuring up to 13 musicians, and performing both traditional tunes as well as specially composed material¹.

At the current stage, performing with *LOERIC* requires a laptop, a dedicated audio interface, microphones and/or MIDI control devices to interact with the system, monitor speakers for the performing musicians, speakers for the audience or a connection to the venue’s public address system, and an experienced operator (the “*LOERIC* wrangler”) who can set up the system, connect it to the relevant input and output devices, and manage its behavior during performance (such as starting it, stopping it, changing tunes, making sure the system is responding as planned, occasionally tweaking its parameters). This introduces a conspicuous logistic overhead, increasing setup time and the complexity of system requirements, reducing the portability and reproducibility of performances and encumbering the musician, both physically and cognitively [4]. Moreover, it makes it impossible for the system to be seamlessly integrated into traditional music practices [5]—especially when playing with otherwise “unplugged” ensembles, like in the case of session playing, a core practice of ITM. How can we simplify the process of deploying the system to allow *LOERIC* to inhabit other spaces of the tradition?

We investigate whether Smart Musical Instruments (SMIs) could help us address these limitations. SMIs extend traditional acoustic instruments through the integration of embedded computing, sensing, actuation, and network capabilities [6]. These instruments can host computational processes locally, incorporate sensors to capture performer gestures and environmental context, and provide feedback through embedded actuators. Furthermore, their wireless connectivity enables integration within the Internet of Musical Things (IoMusT) [7], supporting distributed and networked musical interactions,

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¹An example of such a performance can be seen here: <https://www.youtube.com/watch?v=eOEG9egsCAE>

thus reducing cable encumbering [8], and opening up to new heterogeneous performance ecosystems [9]–[12]. By embedding intelligence directly into the instrument, SMIs offer the potential to reduce reliance on external devices and to enhance the immediacy of performer–system interaction [13].

This work investigates whether SMIs can address LOERIC’s limitations above. Our main research questions are: To what extent can an SMI improve LOERIC’s deployment, in terms of setup complexity and operational overhead reduction? What design characteristics should such an instrument exhibit to effectively support performing and interacting with the system?

Following the design principles reported in [6], we develop the LOERIC-powered smart mandolin we call **MandaLOERIC**. By modifying LOERIC’s architecture and optimizing its performance, we are able to embed it within a compact computing platform, eliminating the need for a separate laptop. Audio input and output capabilities are integrated in the instrument itself, making it self-contained, while networking capabilities allow for on-the-fly configuration through a smartphone, as well as enable the possibilities to communicate with IoMusT ecosystems.

II. MAKING THE MANDALOERIC

We now describe the design process and construction of the MandaLOERIC. From a practice-based perspective, the mandolin was selected due to Amerotti’s experience with it and the availability of an inexpensive instrument to modify. The mandolin is also a traditional instrument used in ITM, which constitutes the primary context of LOERIC’s development. Furthermore, prior work has explored the augmentation of this instrument, including the *Hyper Mandolin* [14] and the *Smart Mandolin* [15].

Drawing on Amerotti’s three years of iterative development of LOERIC, we established a set of design requirements to guide our process. Our goal was to create a standalone instrument that could allow one to readily interact with LOERIC, and possibly be suitable for use in traditional music practice. In order to do so, we aimed to minimize setup time and enable remote control of the system (for example, selecting tunes, adjusting LOERIC’s tempo, or modifying configurations) without reliance on a dedicated computer or traditional peripherals. This leverages lightweight and broadly used devices, such as smartphones, over a standard network connection. Another key requirement was that the interaction with LOERIC should function immediately during performance, without the need for external microphones or audio interfaces, motivating the integration of an internal sensing solution. We also sought to ensure that LOERIC’s audio output could be monitored directly from the mandolin itself while remaining easily routable to external audio systems, such as mixers. Fully integrated onboard sound projection remains an area for future development. Network-based MIDI communication was also considered to reduce constraints imposed by physical proximity to other hardware, enabling flexible integration within distributed performance setups and IoMusT ecosystems. Finally, particular attention was given to

preserving the player’s embodied experience, ensuring that the physical interaction with the instrument remains as close as possible to that of a traditional mandolin despite the introduced modifications. These considerations collectively informed the design decisions and the resulting system described below (See Figure 1).

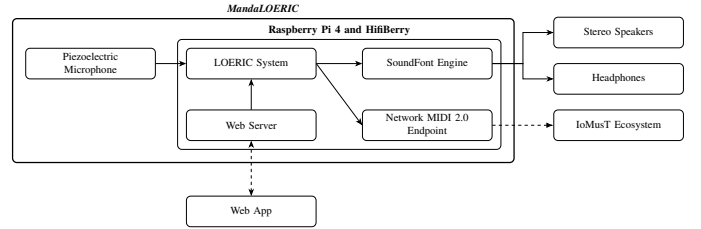


Fig. 1. Block diagram of the software/hardware components that form the MandaLOERIC.

A. Embedded Hardware

We built the system around a Raspberry Pi 4, equipped with a HiFiBerry ADC DAC+ HAT sound card that provides high-fidelity analog input and output up to 192 kHz/24-bit resolution. This hardware combination offers sufficient computational power for running LOERIC, the real-time processing of audio, and network connectivity. Its compact form factor also makes it possible to embed the system directly within the mandolin’s body, thereby avoiding the need for external casing and added weight (already identified by Turchet as an issue with the Smart Mandolin [15]).

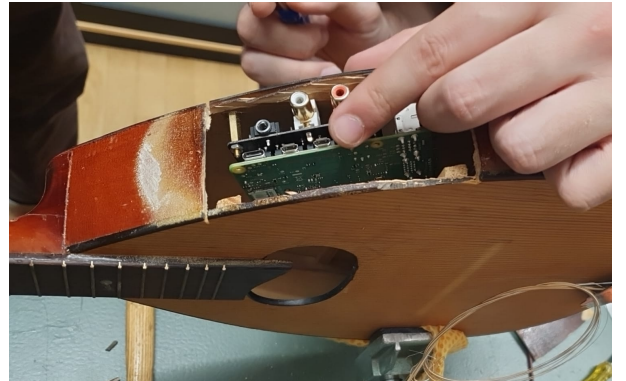


Fig. 2. Raspberry Pi 4 being fitted inside the body of the mandolin.

Figure 2 shows how we modified the instrument by opening one side of the mandolin’s body and mounting the embedded system against the back plate using screws. Particular care was taken to position the hardware so that audio and power connections remain easily accessible while not interfering with standard playing technique. We kept the cutout piece and created a small opening within it for connecting cables, so that it could be reinstalled after positioning the embedded system. This intervention alters the acoustic properties of the instrument: cutting into the body affects the Helmholtz resonance of the mandolin, modifying its natural air cavity behaviour and, possibly, its perceived timbral response.

To capture sound from the instrument, we use a piezoelectric microphone placed inside the body. Being very light and small, the piezo disk can be positioned directly under the bridge, the primary transfer point for string vibrations to the faceplate. This ensures a high signal to noise ratio, as well as isolation from other environmental noises, contrary to an external microphone placed in front of the instrument, which would also somewhat restrict the performer’s ability to move.

B. Software

LOERIC² is a rule-based system written in Python, and can run directly on the Raspberry Pi without needing additional memory. However, the Raspberry Pi’s lower processor speed compared to a standard computer caused issues with real-time performance. We addressed these issues by implementing a series of optimizations throughout the system (e.g., implementing caching where needed, using better search and sort algorithms) and reducing its time resolution of ticks per quarter note to reduce the number of operations per unit time.

LOERIC outputs MIDI data, which can be read through a Network MIDI 2.0 [16] endpoint over standard IP networks, created using *amidi2net*³. The endpoint is discoverable by any compatible Network MIDI 2.0 device or software, enabling seamless integration into an IoMusT ecosystem, and provides low-latency MIDI transmission with built-in packet recovery algorithms to guarantee a continuous performance. Furthermore, LOERIC’s MIDI stream is also audio rendered locally on the Raspberry Pi through a built-in soundfont player based on *TinySoundFont*⁴, whose output is streamed to the Raspberry Pi’s output channels, allowing the user to listen to the system both with headphones or a stereo speaker setup.

C. Remote control

The system can be configured and controlled via a lightweight Python-based web server hosted on the Raspberry Pi, and accessible via any device connected to the same network. In our case, we configured the Raspberry Pi to automatically connect to a mobile network exposed by a standard smartphone. Figure 3 shows the web interface, available through a web browser, providing access to core parameters required to operate LOERIC in performance. The user can select a tune from a library, which contextually loads default parameters for interaction and the kind of tune (e.g. a jig, reel, hornpipe, etc.⁵); choose additional configuration profiles for that tune specifying alternative interaction settings or performance parameters, e.g. associated with different performances of the same tune; select LOERIC’s instrument model, which also changes the system’s sound accordingly; set how many times LOERIC will repeat the tune; transpose LOERIC’s performance up or down, in semitones; set LOERIC’s tempo; set LOERIC’s responsiveness (sensitivity) to the user’s signal; set LOERIC’s output volume; start and stop LOERIC.

²<https://github.com/amerotz/loeric>

³<https://github.com/tiwai/amidi2net>

⁴<https://github.com/schellingb/TinySoundFont>

⁵We direct the reader interested of ITM to, among many, [17].

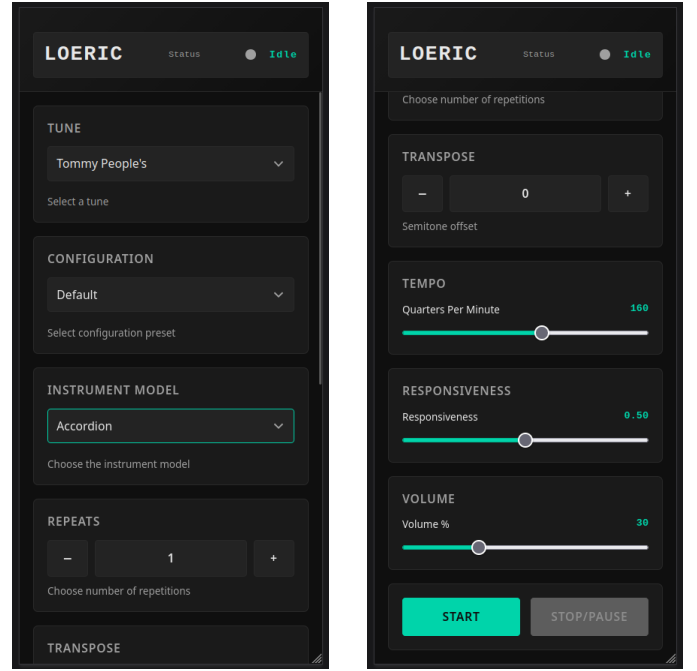


Fig. 3. LOERIC’s configuration page accessed via a smartphone.

Tune, configuration, instrument and number of repeats can only be selected before beginning to play, while tempo, responsiveness, volume and semitone offset can be changed on the fly, allowing the user to fine-tune them during the performance. When the Raspberry Pi is connected to a power source through a standard USB-C cable, it automatically boots, connects to the previously configured network, and starts the server. In case of a software error causing the system to crash, the Raspberry Pi automatically restarts the web server.

III. PRELIMINARY EVALUATION AND DISCUSSION

We conducted a preliminary evaluation based on the direct experience of Amerotti over multiple sessions of solo playing with the MandaLOERIC over the span of two weeks. Insights from this process also prompted us to reflect about how the MandaLOERIC could be integrated with the technological ecosystem around ITM [18], and possible extensions of the platform. The evaluation was deliberately formative in scope. Its aim was to assess the practical feasibility and embodied consequences of integrating LOERIC into a mandolin, and to identify design opportunities and constraints through sustained expert use. Accordingly, the observations below should be interpreted as preliminary design reflections. A systematic technical evaluation is left to future work and a subsequent iteration of the design.

After powering on, MandaLOERIC initializes within ≈ 60 seconds, with the main delay arising from the automatic connection to the mobile network, which may be influenced by the presence of nearby WiFi connections. Otherwise, access to Network MIDI 2.0 functionalities is straightforward, provided one has the required software to discover and connect to the exposed endpoint.



Fig. 4. The final prototype of the MandaLOERIC being held in performance.

Once running, the system requires either speakers or headphones. In the first case, this constitutes the only means of externally listening to LOERIC, which would still limit deployment in unamplified settings. For “unplugged” performances, the lack of a built-in speaker is a primary limitation: external speakers must be sourced, positioned, and connected, and such “invasive” technological involvement might not be acceptable in a traditional context [5]. A possible alternative would be a contact speaker mounted within the instrument; however, this would likely interfere with the piezo microphone and increase power demands.

Headphones, by contrast, enable immediate “solo” use with the MandaLOERIC. This feature could allow learning musicians to practice tunes with LOERIC, which was already identified by practitioners as an interesting use for the system [2], [3]. Moreover, the system shows potential for supporting “learning by ear”, allowing repeated tune playback at variable speeds; perhaps, it could be extended to support more extensive forms of tuition, like other research has done in the case of piping [19]. The piezo microphone enables immediate interaction with effective isolation from ambient noises, and this could be used to analyse the human performance in terms of technique and rhythm, or recognise ornamentation [20].

In terms of control over the system, the current interface only provides basic controls and relies on the existence of a previously curated library of tunes and configuration files that is uploaded to the Raspberry Pi with LOERIC itself, and, as such, new material or interaction settings cannot be easily added at this time. While enabling full configuration editing via the companion application may be complex, integration with a machine-readable online tune repository⁶—also widely used by practitioners—could be a more feasible approach to increasing flexibility and supporting user-curated content. To support session playing, where tunes are usually not known in advance, the MandaLOERIC could be paired with an app like “TunePal” [21] capable of identifying what tune is being played from an audio recording, which could be hosted on the same smartphone controlling LOERIC.

⁶See this website: <https://thesession.org>

The embodied experience with the instrument itself is mostly unaltered by the presence of the Raspberry Pi. Differences in the instrument’s sound are noticeable when removing the “side lid” we cut to accommodate the Raspberry Pi, making the instrument sound “thinner”, but are otherwise not particularly evident with this specific instrument in our experience so far. Power and speaker cables extend away from the performer (See Figure 4), while the headphones cable only occasionally interferes with playing, but in a way not dissimilar from playing with in-ear monitors, or practicing silently at home. In general, the placement of the Raspberry Pi in the instrument does not interfere with playing in the high register, or with how the mandolin is held in performance. The weight and balance of the instrument feel unaltered.

Following the idea of “situated discretion” [5], the minimal visual impact may support acceptance in traditional sessions, as the instrument’s appearance remains largely unchanged and control is handled via a standard smartphone. Future designs could better integrate embedded hardware with input from a luthier, or intentionally expose technological elements as decorative features, as in the Carolan Guitar [22]. On the contrary, the absence of significant affordance limitations could be exploited to integrate onboard sensors like on the Hyper Mandolin [14], or additional control devices like the Stretchy Strap [23].

Finally, a notable advantage is the elimination of a laptop. This allows performers to operate LOERIC without a keyboard or large display, avoiding the need to interrupt playing to manage a computer. Rapid selection of tunes and parameters, along with control over sound, volume, and tempo, makes interaction more immediate and enjoyable, enabling greater focus on performance without repeated system reconfiguration.

IV. CONCLUSION

This paper presented the design and implementation of MandaLOERIC, a smart mandolin embedding the LOERIC rule-based performance system into a self-contained musical instrument. Starting from the practical limitations associated with deploying LOERIC in live performance and in a traditional context such as sessions, we translated a set of experiential requirements into concrete hardware and software design decisions, and reflected on how these relate to wider themes in augmented instrument design and traditional practice.

From the perspective of SMI design, MandaLOERIC illustrates how embedding an existing AI performance system within an instrument can reconfigure the relationship between musicians, technologies, and performance ecologies. By hosting LOERIC locally and making it accessible via a familiar physical artifact, the instrument moves some of the decision-making and configuration work from the laptop and mixing desk into the musician’s hands. This resonates with broader trajectories in IoMusT, where instruments act as intelligent, networked nodes that mediate between performers, audiences, and distributed computational infrastructures.

However, our observations foreground the importance of practical factors such as power management, robust network

connectivity, and sound projection in determining whether such systems can truly support everyday musical practice. Our prototype also surfaces several limitations and opportunities for future work. The need for external speakers or headphones to hear LOERIC, and the absence of a built-in transducer, currently constrain deployment in unplugged or informal contexts, and highlight the importance of integrated actuation for fully self-contained SMIs. Similarly, the dependency on external WiFi and smartphone-based control may be problematic in environments with limited or unreliable connectivity. Alternative power and control strategies could be explored, as well as other interaction modalities leveraging onboard sensing or more complex analysis of audio beyond acoustic amplitude.

Having future research in mind, MandaLOERIC provides a starting point for investigating how LOERIC can be migrated from laptop-based setups into embedded, instrument-centric forms, and their potential to support traditional practice beyond amplified live performance. Embedding the AI system into a self-contained instrument allows us to more easily bring the system to practitioners (e.g., by physically giving them the MandaLOERIC and a pre-configured smartphone), and, eventually, to sessions, and start exploring what LOERIC's role might be in these new scenarios. At the same time, it could also power creative explorations with music AI: for example, the augmented mandolin could also become an interface for embodied interaction with LOERIC through sensors or soft robotics, or even for LOERIC itself to play a physical instrument.

More broadly, while our work is grounded in Irish traditional music and the specific affordances of the mandolin, we speculate many of the principles we adopted—compact embedded architectures, onboard sensing and audio, lightweight networked control, and alignment with musicians' embodied practices—could generalise to other instruments or other music AI systems with low computational needs, like LOERIC.

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