# PhysioDrum: Bridging Physical and Digital Realms in Immersive Musical Interaction

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## Abstract

The Internet of Multisensory, Multimedia, and Musical Things (Io3MT) bridges computer science, humanities, and arts, fostering transmedia services and creative applications. This demo research applies these principles alongside extended reality (XR) to enhance PhysioDrum, an immersive, multimodal system that blends physical and digital aspects to expand musical expression in virtual environments. Using a smart musical instrument (SMI) and electronic pedals as interfaces, users interact with a virtual drum kit through gestures while receiving haptic feedback. By integrating sound and multimedia elements, PhysioDrum aims to reduces cognitive load and the learning curve, merging traditional drumming practices with immersive XR. The demo emphasizes design strategies that enhance playability, accessibility, and creative potential for users of all skill levels.

## CCS Concepts

• **Applied computing** → **Performing arts**; • **Hardware** → *Sensors and actuators.*

## Keywords

Io3MT, Extended Reality, Immersive Environments, Artistic Creation, Virtual Drum

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## 1 Introduction

The Internet of Multisensory, Multimedia and Musical Things (Io3MT) [7] is a domain emerging from the intersection of computer science, arts, and humanities. Io3MT advocates the integration of those three types of information within a unified system, allowing those modalities to interact fluidly, interchangeably, and without hierarchical constraints. Conversely, multimedia elements such as videos and images can be audio-reactive, adjusting color patterns or movement speeds in response to sound stimuli, while multisensory elements can be activated by audiovisual information. This approach results in a network of heterogeneous devices that combine real-world and digital data to generate new creative applications, exploring multimodal, multiplatform, and transmedia interactions.

In recent years, academic, artistic, and industrial initiatives have witnessed significant growth at the intersection of musical practice and extended reality (XR), culminating in the emergence of the concept of the Musical Metaverse (MM) [5]. This domain encompasses the study and development of virtual environments designed specifically for musical activities. While this convergence marks a departure from traditional artistic paradigms, enabling novel interactions between artists, audiences, objects, agents, and virtual environments, the state of the art has predominantly concentrated on enhancing audience experiences, with a particular emphasis on visual elements. In contrast, critical aspects such as music production and sensory effects often receive secondary attention [6, 9].

In this context, the Internet of Multisensory, Multimedia, and Musical Things (Io3MT) emerges as a promising framework for bridging the gap between the Musical Metaverse (MM) and the physical world, effectively addressing the challenges previously identified. By enabling seamless integration, Io3MT is positioned to play a crucial role in virtual and immersive musical applications, fostering greater engagement from both artists and audiences in the co-creation and experience of musical processes. Consequently, Io3MT serves as a fundamental link between traditional analog and physical musical practices and the digitally constructed environments of the MM, promoting a cohesive and interactive relationship across these domains [6].

This demo explores the application of Musical Metaverse concepts through the extension of an immersive, multimodal, and interoperable system called PhysioDrum[1][2][9]. This application utilizes a smart musical instrument (SMI) [4], the RemixDrum [8], along with two electronic pedals as a control interface. This setup enables the reception of haptic feedback and the transmission of data to various multimedia applications. The primary objective of this study is to present an interactive installation that enhances


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[1] GitHub: https://github.com/romulovieira-me/PhysioDrum/tree/main
[2] Video: https://www.youtube.com/watch?v=EGDFz3pzZWg

musical expression within an extended reality (XR) framework. By introducing novel interactions, the system enables users to translate creative ideas and physical movements into virtual environments, seamlessly bridging the physical and digital realms.

The remainder of this paper is organized as follows. Section 2 describes the main operational guidelines that govern PhysioDrum. Section 3 details the practical implementation of the system, including its architecture, the hardware and software components utilized, the innovations introduced by this work, and specifics regarding its presentation at the conference. Finally, Section 4 presents the conclusions of the study and proposes directions for future research.

## 2 Environment Design

Some general points should be taken into account when designing XR music services, such as considering diverse perspectives, creating engaging environments, promoting freedom of navigation, and generating immersive experiences that enhance user enjoyment. This demo integrates these elements, aligning with the five design guidelines for immersive applications based on the Io3MT framework [9], summarized below:

- **Design for Functionality:** Artistic applications, though playful, must be robust and goal-oriented, enabling effective expression of ideas and emotions. Key features include synchronization, low latency, realistic dynamics, ergonomic interfaces, and user comfort.
- **Design for Immersiveness:** The application should provide coherent sensorimotor contingencies and clarify system limitations. Immersion is enhanced by high-quality audio, body ownership, visual fidelity, precise motion tracking, and aesthetic elements.
- **Design for Feedback:** Feedback, whether auditory, visual, or multimodal (e.g., haptic), enriches user engagement and comprehension, enhancing the overall immersive experience.
- **Design for Social Connection:** Applications should support shared experiences, enabling real-time communication and fluid collaboration in both co-located and remote scenarios.
- **Design for Creativity:** Beyond artistic performance, applications should facilitate music education, creative experimentation, and exploratory or recreational activities.

## 3 Operational Mode

The application was developed in Unity 2022.3.30, utilizing Quest 3 and Meta Interaction SDK V1.3.2. It features a virtual drum kit that represents traditional drum set components, including a bass drum, snare, floor tom, two toms, ride cymbal, and hi-hat. Interaction with these elements occurs through physical actions performed with the RemixDrum and pedals, resulting in a fluid and intuitive experience. In the third version of RemixDrum, developed as part of this study, colored spheres were integrated, whose movements are captured and processed by a computer vision algorithm implemented in Python 3.8. This algorithm analyzes the displacement of the spheres and converts them into digital commands, enabling interaction between the physical environment and the virtual application. Additionally, a coin vibration motor was incorporated into the electrical circuit to provide haptic feedback to users, enhancing the sensory perception of collisions in the virtual drum set.

The pedals used in the system are connected to an electrical circuit that detects when they are pressed and sends this information to the virtual application through Open Sound Control (OSC) messages. These devices simulate the behavior of traditional drum pedals, triggering the sound of the bass drum and hi-hat. Although they differ from conventional devices in aesthetics and ergonomics, they replicate their functionality in a consistent manner.

This operational mode, which leverages physical movements to control and trigger properties in the digital world, is rooted in the concept of phygital (physical plus digital) [1]. As the name implies, this approach integrates physical and digital processes, establishing connections and networks that bridge these domains to enable novel functionalities and forms of interaction.

The sound generated by the drums is combined with the synthesized audio in Pure Data, while graphical interactions in Processing create a multimodal remix of content. The system was run on an ASUS TUF Gaming F15 laptop, equipped with an NVIDIA GeForce RTX 4050 graphics card, Intel i7 processor, and 16GB of RAM. Figure 1 illustrates this architecture, while Figure 2 shows the equipment used in this interaction, as well as the live virtual application.

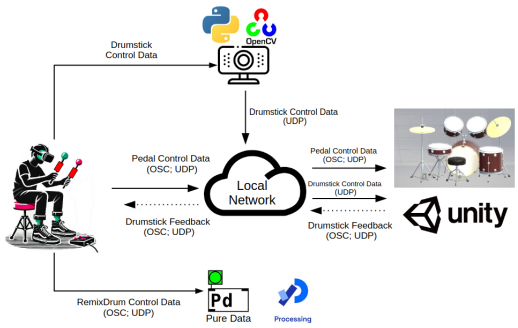


**Figure 1: PhysioDrum Architecture.**

This system configuration sets PhysioDrum apart from similar air drumming applications [2, 3, 10–13] by incorporating both haptic feedback and pedal-based control. While other systems often rely on computer vision to capture foot movements and omit haptic feedback, PhysioDrum addresses these elements comprehensively.

It is important to emphasize that the goal of this project is not to fully replicate a traditional drum set within a digital environment. Certain techniques, such as rim shots, ghost notes, and buzz rolls, present challenges in this context and are difficult to reproduce with high fidelity. Instead, the focus is on emulating key behaviors and leveraging metaphors from traditional drumming practices to create an intuitive and engaging experience. This approach aims to enhance fidelity, interactivity, and user engagement in musical applications within the XR domain. By prioritizing these aspects, the system paves the way for the development of networked solutions that are immersive, accessible, and interoperable, ultimately improving playability and enriching the overall musical experience. From an artistic perspective, the combination of musical factors with tactile elements, multisensory feedback and increased physicality


(a) RemixDrum 3.0. (b) Case and electronic pedals. (c) Physiodrum live environment.

**Figure 2: PhysioDrum equipment and virtual scenario.**

of the virtual environment creates new possibilities for abstraction, immersion and creativity.

To demonstrate the system, experienced users will be able to freely explore the application, while beginners will have access to a standalone, game-like experience where they will have to perform basic tasks such as reproducing musical patterns and rhythms. This approach broadens the scope of the application, making it accessible to both experienced and beginner users.

## 4 Final Remarks

The development of PhysioDrum was a challenging and interdisciplinary endeavor, requiring advanced expertise in areas such as virtual reality, computer networks, signal processing, electronics, sound design, and core concepts of music. The target audience for this research includes musicians, educationalists, researchers at the intersection of music and technology, and industry professionals exploring physicality in virtual applications.

The main contributions of this work include the incorporation of the phygital concept, the integration of haptic feedback and pedal-based controls, the creation of a new use case within the Io3MT domain, and the proposal of strategies to address existing gaps in the fields of the Musical Metaverse and XR applied to the arts. These innovations have the potential to inspire *avant-garde* artistic presentations and open new possibilities for designing interactive and customizable environments. The integration of immersive elements with multisensory information further enables new forms of artistic expression and narrative, fostering deeper and more meaningful connections with musical content.

Future work will involve conducting qualitative user evaluations to assess the effectiveness of haptic feedback, explore the cognitive load associated with the system, and establish metrics for evaluating interface quality. These studies will provide valuable insights to refine the application, contributing to its advancement and solidifying its role as a significant tool in the field of immersive and interactive musical applications.

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