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Research Article

An Emotion-Driven Interaction Framework for Internet of Musical Things

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Abstract: The Internet of Musical Things connects smart instruments, wearable devices, and musical tools using the Internet of Things, Artificial Intelligence and Semantic Web technologies. Previous studies have improved semantic interoperability and network efficiency but they primarily focused on technical aspects overlooking usability and cultural inclusivity. This paper reviews existing contributions to identify gaps such as complex interfaces and insufficient validation. To address these issues, we propose an intuitive, feedback-enabled, and emotion-aware graphical interface for non-technical users. The methodology emphasizes requirement analysis, user-friendly design, feedback integration through usability and adaptability, thereby bridging technical infrastructure and real-world applications.

Keywords: Internet of Musical Things (IoMusT), Semantic Web, Ontology, Emotion-aware Interface, Music Technology.

INTRODUCTION

The relationship between music and technology has always been a common ground always calling up for innovation, starting from the early invention of instruments to the digital revolution [Fig 1] . In recent years, advancements in the fields of Internet of Things (IoT), Artificial Intelligence (AI), and Semantic Web technologies have given rise to a new domain combining these known as The Internet of Musical Things (IoMusT) [1] [2] . IoMust refers to an ecosystem where musical devices, instruments, and systems interconnect and interact with each other seamlessly across networks. IoMusT is aimed at imagining a world encompassing smart instruments, wearables, mobile devices, and distributed platforms to provide new forms of performance, learning, and greater audience engagement to users [3]. This standard not only changes musical creativity but also opens the gates for many new opportunities in the fields of education, therapy, and cultural heritage.

Fig.1 Evolution of music and technology: from mechanical instruments to IoMusT.

One of the most crucial segments of IoMusT includes use of semantic technologies and ontologies. Semantics refers to the interpretation of data, enabling machines to process information in a way that is similar to human understanding. In IoMusT, semantics help in converting the raw musical data into information by enriching it with context and relationships which makes the data meaningful and easier to search upon [4]. An ontology is a structured and formal representation of knowledge that defines concepts, relationships, and rules within a particular domain. In the field of IoMusT, ontologies are used to describe musical instruments, performances, metadata, and interactions in a machine-readable way which allows interoperability among heterogeneous systems and datasets [Fig 2]. Various ontologies such Smart Musical Instruments Ontology (SMI) [5], the Music Meta Ontology (MMO) [6], the Music Note Ontology (MNO) [7], and the Polifonia Ontology Network [8] provide frameworks which are readable by the machine in order to describe and interlink musical resources. These allow heterogeneous data sources including audio, metadata, symbolic notation, and performance contexts to be represented and queried in an interoperable way. Together, these advancements underscore the growing approaches in the IoMusT landscape.

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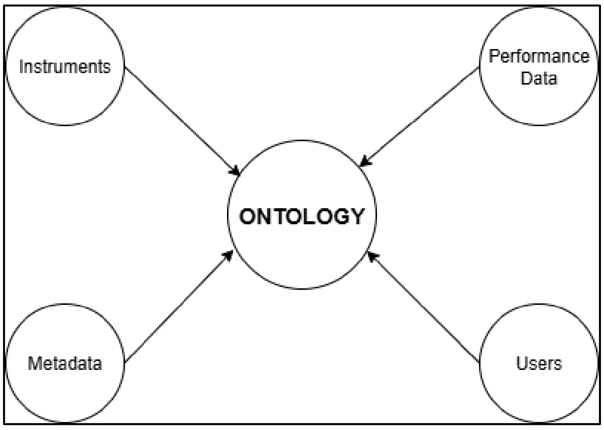

Fig.2 Role of ontology in IoMusT, connecting instruments, metadata, users, and performance data.

Despite this progress, several limitations still persist. Many of the existing studies are either narrow in scope or purely conceptual as they address single aspects such as metadata interoperability, edge computing for latency reduction or auto-tagging of musical pieces [9]. No doubt these efforts are of immense importance technically but they still lack holistic integration in terms of emotional and user centred perspective. For example, models that enrich MIDI with semantic metadata do not extend to multimodal data such as gestures and real-time performance cues. Similarly, the systems designed for music education tend to focus on technical training and tend neglect creativity. These reasons pose a restriction to musicians, educators, and cultural practitioners to utilize IoMust facilities to the fullest.

Another important drawback lies in the lack of emotion-awareness and cultural inclusivity in IoMusT research. Music tends to be expressive and culturally embedding by nature but most technical solutions reduce it to symbolic or structural features. Additionally, the majority of research outputs are prototypes without large-scale validation, making it unclear how these systems perform in real-world with different types of users. The absence of intuitive user interfaces create a division between advanced semantic infrastructures and practical usability overlooking the idea of broader adoption of IoMust.

The swift expansion of smart technologies and connected ecosystems has transformed how people create, share, and experience music. However, most IoMusT initiatives are limited to laboratory prototypes and fragmented applications which prevents their usage in day-to-day musical practices. With the rise in demand for accessible digital tools in education and cultural preservation there is an immediate requirement for IoMusT systems that cater not only to technical efficiency but are human-centred, inclusive, and emotionally responsive at the same time.

1.1 Contributions

a) This work proposes research in the domain of Internet of Musical Things (IoMusT) by shifting the focus from purely technical solutions to a greater view and a scalable vision including usability, inclusivity, and real-world adoption of the models.

b) Most of the earlier studies were focused on protocols, metadata standards and theoretical frameworks, this research highlights the need of designing systems that are intuitive, emotionally engaging, and accessible to a wide range of users.

c) This work is motivated by the idea of bridging this gap by exploring various interfaces and frameworks that convert complex IoMusT infrastructures into intuitive and real-world solutions that can turn out to be advantageous for the community.

LITERATURE SURVEY

Recent advancements in the domain of Internet of Musical Things (IoMusT) highlight both technical and socio-cultural perspectives. For instance, *Possibilities Emerging on the Trajectory from IoT to IoMusT* [19] explores how ubiquitous musical interactions can support wellbeing, therapy, and everyday engagement with music depicting the future of IoMusT not only in the technical ecosystem but also in the areas of improving health and quality of life. *The Internet of Musical Stuff* [25] tends to reimagine IoMusT aesthetically by discussing how decentralized creativity and digital communities are responsible for shaping the future of musical networks.

In the field of interoperability, *Sunflower*[17] proposes a standardized communication environment that allows musical devices and systems to exchange messages efficiently and in a standardized manner. Similarly, *Is Music in the Air?* [24] evaluates the role of 4G and 5G networks in networked music performance whose results have the ability to depict how low-latency communication is essential for real-time collaborations.

In terms of interfaces works such as *Air Piano Interaction via Flex Sensors and Computer Vision* [5] and *An Ubiquitous Smart Guitar System* [6] present innovative prototypes that enable music-making through gesture recognition, embedded sensors, and mobile applications. In the field of music education, *Designing an Educational Musical Software: Synth4Kids* [7] combines both traditional and game-based design in a web-based synthesizer for children in order to improve the quality of music education.

Ethical issues are addressed in *An Ethics Framework for the Internet of Musical Things* [8], that adapts AI principles in order to ensure fairness, transparency, and wellbeing of IoMusT applications. Finally, *Issues and Challenges of Audio Technologies for the Musical Metaverse* [9] critically examine latency, hardware constraints, and interoperability barriers that limit immersive musical environments, providing insights for future research. Tools and techniques have been elaborated in detail [Table 1] .

Table 1: Overview of selected IoMusT studies.

Year	Briefs	Tools & Techniques	Advantages	Disadvantages	Dataset Used
2019	Prototype smart guitar with mobile app.	Smart guitar hardware, Pure Data, MobMuPlat, Ubimus design.	Bridges traditional instruments with mobile tech.	Prototype only and lacks AI integration.	-
2020	Framework of audience/musician interaction, technology, business models, and privacy issues.	Conceptual modelling and IoT application design, framework for live performance enhancements.	Offers the first structured IoT framing for enhancing live music experiences.	Only conceptual, lacks implementation and evaluation.	-
2021	Proposes a standardized communication environment/protocol for IoMusT.	Middleware design, pipes and filters, architectural pattern and predefined message formats.	Provides an implementable protocol that promotes standardization for IoMusT deployments.	Focuses on communication protocols, does not include semantic layers.	-
2022	Web-based synthesizer for children.	Web app, analog synthesis, tilt & touch sensors.	Makes early music learning playful.	Prototype only; no IoMusT/AI integration.	-
2022	Explores the transition from IoT to IoMusT, focussing on ubiquitous musical interactions for wellbeing.	IoT/IoMusT architectures, wearable sensors, mobile and wireless systems, ubiquitous computing, HCI frameworks.	IoMusT scope in health and wellbeing.	Limited technical implementation and lacks semantic integration.	-
2023	Web system enabling singers to use smartphones in choir for remote setups.	Web app, smartphones, networked music performance.	Expands choral practice.	No semantic/AI integration.	-
2024	Proposes an ethics by design framework to IoMusT systems.	Conceptual ethical framework aligned with Trustworthy AI guidelines.	Addresses an underexplored but critical area IoMusT ethics.	No technical implementation or IoMusT system validation.	-
2024	Introduces IoMusT that integrates people, devices, and environment.	HCI entanglement theory, ethics-by-design framework.	Broadens IoMusT by including ethics, sustainabilit.	Conceptual only, no implementation or validation.	-
2024	Proposes (MusicTalk) for musical instrument recognition with brightness patchout.	IoTtalk platform, Vision Transformer CNN, Audio shaper, Grad-CAM.	High accuracy, scalable design and explainable predictions.	Limited real-time evaluation, less tested on non-Western/noisy instruments.	Public audio datasets for instrument recognition (e.g., NSynth, IRMAS)
2024	A detailed evaluation of network performance for	System level simulations using 5G-LENA/ns3 and Simu5G/OMNeT++.	Evidence that 5G significantly outperforms 4G	Focuses on network performance only and lacks	5G-LENA/ns-3, Simu5G/OMNe

	IoMusT comparing 4G and 5G in terms of realistic networked music performance.		for multiple IoMusT devices.	semantic modelling.	T++, plus user survey data.
2024	Introduces the IoMuSt concept reframing the Internet of Musical Things aesthetically for society.	Ubimus (Ubiquitous Music) frameworks, online collaborative music platform and discourse on blockchain.	Expands IoMusT discourse beyond technology into aesthetics, community, and cultural sustainability.	Lacks concrete technological systems, semantic interoperability.	-
2024	Enables "air piano" interaction using flex sensors and computer vision.	Flex sensors for finger angle detection, computer vision gesture tracking, real-time edge processing.	Demonstrates an innovative, low-cost gestural musical interface.	Prototype level with no semantic integration.	-
2025	Reviews audio technologies highlighting barriers such as hardware/software limitations and high latency.	Analysis of current consumer audio systems, network/audio delays.	Clear, empirical identification of real-time audio.	Focuses on diagnosis only, no semantic, or AI-driven solutions.	-
2025	Introduces the Io3MT concept integrating multisensory, multimedia, and music devices into a unified environment.	Multisensory integration (audio, visual, tactile), device/protocol interface modelling and QoS benchmarking.	Creates an operational Io3MT prototype with practical evaluation.	Lacks semantic layer integration (ontologies), AI features, or user-cantered adaptivity.	Simulation + QoS benchmarking datasets

3. Knowledge Gaps

The following are the knowledge gaps in the State of the Art:

A) Applications in Semantic Web Technologies in Music Production (2014)

This work makes use of semantic web standards (RDF, OWL, SPARQL) to music production metadata and workflows. However, the scope is confined to studio settings and does not extend into IoMusT contexts such as smart instruments or real-time musical collaborations. The lack of multimodal integration limits its relevance to interactive music. While metadata organization is improved, the framework was never tested with real musicians or producers, making it vague whether it could be adopted by the non-technical users. Scalability concerns are also left unaddressed in this paper.

B) Building Interoperable and Cross-Domain Semantic Web of Things Applications (2017)

This paper presents a valuable semantic interoperability engine (M3 framework), but it is domain-general and not customized to music. As a result, it does not consider the latency constraints of live performance and the emotional qualities of musical data. Moreover, the framework was only validated conceptually without any demonstrations involving musicians or musical devices. The absence of user-facing tools makes it difficult to measure the framework's accessibility or practical benefits for music stakeholders.

C) Internet of Music Things: Edge Computing for Opportunistic Crowdsensing (2018)

The authors address scalability by combining edge, fog, and cloud computing for IoMusT. However, their focus is on network performance rather than semantic interoperability or music-specific applications. Without semantic descriptions, musical data collected by sensors remains isolated and difficult to reuse. The study also oversees educational and creative use-cases where latency and scalability would need to be tested as well to provide a better user experience, which makes the architecture technically sound but disconnected from real-world musical practices.

D) The Semantic Web MIDI Tape (2018)

This paper bridges MIDI(Musical Instrument Digital Interface) with semantic metadata, improving retrieval and contextual understanding. Yet, the framework is limited to symbolic MIDI files and does not include audio recordings, gesture data, or multimodal information. Emotional characteristics of music are disregarded, reducing its applicability in the cultural and creative domains. While useful for retrieval tasks, the lack of large-scale evaluation makes it unclear how effective the system would be in real-world applications.

E) DewMusic: Crowdsourcing-based IoMusT in Dew Computing (2020)

By proposing a dew fog cloud hierarchy for IoMusT, this study enhances latency and energy efficiency. However, the design is completely focused on the architecture, regardless of the semantic or ontological integration to make musical data interoperable. The system was never tested with actual users, so it remains uncertain whether musicians could meaningfully benefit from the infrastructure. Security and privacy challenges, especially for crowdsourced data, are only mentioned conceptually, leaving a gap in terms of real-world adoption.

F) Populating the Smart Musical Instruments Ontology with Data (2020)

The paper demonstrates ontology population with real-world smart instrument data. While useful, it is confined to metadata enrichment and does not extend into creative applications such as compositions and learning. Linkage with other ontologies is not considered which is responsible for limiting the interoperability at broader levels. Furthermore, absence of relative studies to evaluate whether non-technical users could explore the ontology effectively.

G) Mastering Music Instruments through Technology in Solo Learning Sessions (2020)

This work highlights sensor-based feedback for learners. The gap here lies in its lack of semantic integration with broader IoMusT systems. Feedback is rule-based and technical, without emotional or expressive awareness thus reducing the musical authenticity. The validation was limited to small user studies due to which the generalization to larger populations still remains unclear. Importantly, the absence of ontology-driven interoperability restricts its integration with smart instruments or cultural repositories.

H) On the Relation Between Networked Music Performance, Ubiquitous Music, and IoMusT (2022)

The authors offer a strong theoretical synthesis of three paradigms and propose MUSEPA. However, it is purely theoretical with no empirical validation through prototypes or deployments. No semantic or ontological framework is provided to make the proposed ideas operationally active. The work also lacks evaluation of latency and usability, leaving the practical feasibility of MUSEPA unexplored.

I) The Music Note Ontology (2023)

This ontology models symbolic music notation semantically. The limitation here lies in its symbolic only focus, excluding audio, gestures, or multimodal performance of data. Without real-time mapping to performances, its applicability in IoMusT is restricted. Emotional dimensions of notation are not modelled which are responsible for reducing its usefulness for affect-aware music systems. The ontology has not been tested within IoMusT pipelines, so its role still remains unclear in real life interactions.

J) Smart Musical Instruments Ontology (2023)

This ontology defines semantic descriptions for smart instruments, an important step for IoMusT. Yet it is instrument-centric and does not link to repositories, cultural heritage, or performance data. Real-time constraints such as latency are not modelled which leaves open the question related to its use in live setups. No usability validation with musicians or educators was performed. Furthermore, security and ethics implications of capturing data from smart instruments are not addressed.

K) The Polifonia Ontology Network (2023)

The ontology is related to cultural heritage data, but it is heritage first and not optimized for real-time IoMusT. As such, it cannot support interactive performances or learning contexts effectively. Cross-mapping with device ontologies is not yet developed up to the desired levels which limits interoperability. Large-scale performance testing is missing, raising questions about scalability. Emotional and cognitive aspects of musical experiences are also absent.

L) The Music Meta Ontology (2023)

This ontology merges heterogeneous music metadata sources. However, it is restricted to metadata and does not cover emotional and sensor-based dimensions of music. Interoperability across multiple ontologies is not fully demonstrated. Query performance at large scale is not evaluated, leaving open the question of its scalability. Finally, no user studies are provided to assess whether non-experts can benefit from this ontology.

M) OnSET: Ontology and Semantic Exploration Toolkit (2025)

OnSET improves ontology exploration but is not IoMusT-specific. It does not offer music-oriented filters, making it generic rather than specialized. No connectors to live IoMusT device streams are included, limiting its applications in real-time. Usability testing is missing, so accessibility for musicians still remains unproven. Additionally, no support for explainable queries in music education contexts is provided.

N) Semantic-Aware Interpretable Multimodal Music Auto-Tagging (2025)

This paper advances interpretable AI for tagging, using multimodal fusion. The main gap is its narrow focus on auto-tagging rather than IoMusT interoperability. It is not linked to ontologies like SMI (Smart Musical Instruments Ontology) or MMO

(Music Meta Ontology), reducing its semantic impact. The system is tested on benchmark datasets but not in real-time or live music scenarios, limiting its IoMusT relevance. Cultural coverage is biased towards Western datasets, and no interactive feedback loop is integrated to refine the results based on user input.

Summary of Gaps

Several gaps emerge witnessing works in this domain. Metadata-focused approaches [1], [2], [4], [9] offer strong interoperability but fall short in creativity and emotional engagement with user. Infrastructure-oriented studies [3], [5], [8] improve latency but overlook the semantics and user experience. Ontology-driven research [6], [10], [11], [12] standardizes representation but remains domain-specific in nature. AI-semantic integrations [14] advance explainability but lack the broader view of deployment in IoMusT ecosystems. The overall route of progression of the researches starting from metadata workflows leading AI–semantic convergence still fall short to fully resolve the challenges of emotional awareness, multimodal adaptability, and real-time interoperability.

4 Problem Formulation

The main aim of this research is to design and develop an intuitive, feedback-enabled, and emotionally-aware graphical user interface (GUI) for IoMusT applications that ensures accessibility for musicians, learners, and educators, regardless of their technical expertise.

4.1 Objectives

This study outlines the following detailed objectives:

A. **Simplify Access to IoMusT Systems**
Many existing IoMusT systems are technically complex and require users to interact with command-line tools and coding frameworks. This research aims to overcome this limitation by providing a user-friendly interface that reduces the technical complexity and presents system functionality through clear menus, icons, and buttons. The GUI will serve as an entry point where users can connect devices, explore features, and interact with musical data without the need of technical knowledge.

B. **Enable Real-Time Feedback and Interaction**
For learners and educators, feedback is one of the most critical elements for an effective music education. The proposed interface will integrate feedback mechanisms that allow users to receive immediate responses during practice or performance. For example, learners could be informed if their tempo or pitch deviates from the desired ones, while educators could use the system to provide structured guidance. This GUI would help turning IoMusT from a purely technical system into a supportive learning companion.

C. **Integrate Emotional Awareness in Music Interaction**
Music is deeply emotional and expressive, yet many IoMusT systems reduce it to symbolic or structural features. This study seeks to integrate emotional tagging and awareness into the GUI. Users will be able to assign emotional contexts (e.g., happy, calm, melancholic) to music pieces or select moods they wish to generate or explore upon. The system would be capable enough to adapt recommendations, modify playback, make the interaction more human-centred and culturally inclusive.

D. **Support Multimodal and Inclusive Access**
The GUI will be designed with the aim to support multiple input modes such as audio, MIDI, or symbolic notation. This ensures inclusivity for musicians working with different formats and with various cultural traditions. By accommodating varied input and interaction styles, the system will broaden the scope of IoMusT applications beyond Western notation or MIDI-centred systems.

E. **Promote Usability for Non-Technical Users**
The central aim is to ensure that IoMusT systems are not only limited to researchers and advanced developers but can be also adopted by everyday musicians, learners, and educators. The proposed GUI will be evaluated in terms of accessibility, clarity, and ease of use, highlighting how it is capable of bridging the gap between sophisticated back-end semantic infrastructures and practical usage in the real-world environments.

METHODOLOGY

The proposed methodology is organized into four stages [Fig 3] :

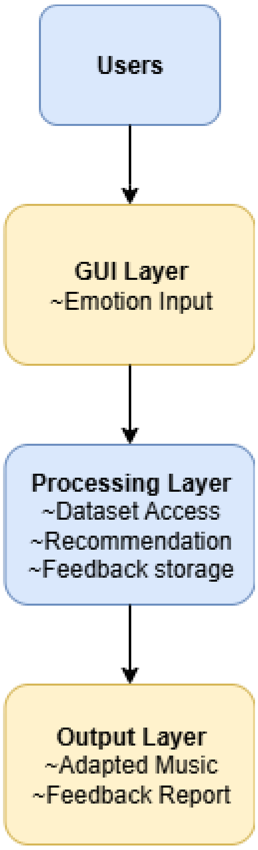

Fig.3 Proposed architecture of the emotion-aware and feedback-enabled GUI for IoMusT.

A. Requirement Analysis

The first stage involves identifying the needs of target users consisting of musicians, learners, and educators. This can be achieved by reviewing existing literature and analysing gaps of the present IoMusT systems. These systems are often complex, require technical expertise to operate. Most of the times they tend to oversee the emotional and cultural aspects related to the music. From this analysis, functional requirements are established such as simple navigation, multimodal support, emotional interaction, and real-time feedback.

B. Interface Design

The major contribution of this work is based on the development of a user-friendly GUI. The interface will be designed using prototyping tools such as Figma or simple web-based frameworks in order to make is easily usable by the non-technical users. The features of the GUI would include:

a) **Emotion Selector:** Users would have the freedom to choose the mood in order to cater their exploration towards music (Eg: joy, sadness, calmness, excitement).
b) **Music Data Panel:** It would display information related to instruments and genre. A sample dataset would be used to mimic the working of music repositories.
c) **Visualization Tools:** Some interactive elements consisting of category exploration and graphs to depict the relationship between data would be used.
d) **Accessibility Icons:** Icons accompanied by guided menus and clear navigation would be introduced to fulfil our proposed idea of usage by non-technical users.

C. Feedback Mechanism

In order to enhance the adaptability of the system it would be incorporated with a feedback loop. Users would be able to rate the outputs based on relevance, emotional fit and usability. This feedback would also be stores in the structural format for later use.

D. Evaluation

The evaluation of the proposed system would be both conceptual and comparative. Unlike the earlier works that were mainly theoretical or prototype based, this model would incorporate:

a) Usability: Ease of usage of the model by every kind of users.
b) Emotional-awareness: It would try to retain the emotional aspect that is linked to the music.
c) Adaptability: It would be potential enough to incorporate user feedback into future system refinements.
d) Accessibility: It would be accessible in terms of its suitability towards musicians, instructors and learners.

5. Existing Interfaces

Before presenting the proposed interface, it is important to review some of the existing GUIs developed in related domains of IoMusT research.

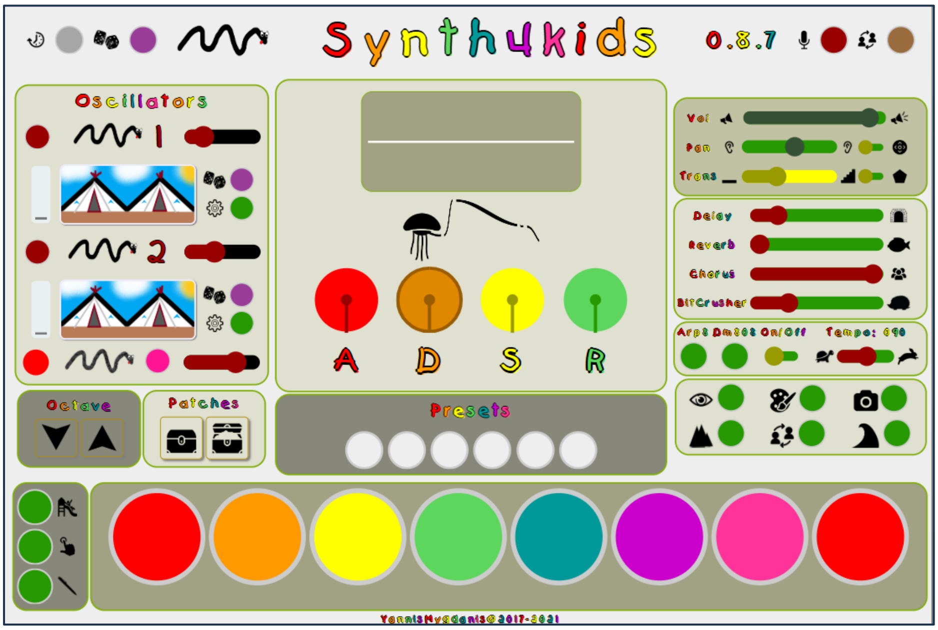

Fig.4 Existing educational interface: Synth4Kids, a prototype software designed for children's music learning. Designing an Educational Musical Software: The Case of Synth4Kids

The *Synth4Kids* [Fig 4] software was designed as an educational synthesizer that has the capability to blend traditional music education with interactive, game-based elements with the aim to enhance the learning and teaching experience for both students as well as teachers. Its web-based environment enables children to engage with music creatively by using simple gestures and playful interaction. However, the system remains limited in scope, as it does not integrate with broader IoMusT frameworks or support emotion-aware features, thereby restricting its usability beyond early-stage music learning.

Working of Synth4kids

A. User Interface (GUI)

a) The software encompasses colourful, kid-friendly GUI with buttons, sliders, and icons.

b) Children interact with it by pressing buttons to play notes, moving sliders to change pitch, or using touch/tilt controls.

B. Sound Generation

a) It uses a synthesizer engine in order to produce different tones.

b) For example, sliding a control might increase pitch mimicking the act of moving up in the piano.

C. Sensors

a) **Tilt sensors** → children can tilt a device (like a tablet) to modulate sound.

b) **Touch inputs** → touchscreen controls let kids adjust sound parameters.

D. Pedagogical Integration

The software is designed using traditional music-teaching such as scales, rhythms and simple melodies. It turns them into interactive, playful tasks (like games).

E. Learning Experience

a) Kids not only just hear the notes but they also see colourful visual feedbacks.

b) The GUI helps them associate sound with action and visual cues.

Strengths

a) Makes early music learning fun for students.

b) GUI is intuitive and accessible for kids.

c) Encourages exploration through play, not just theory.

Limitations

a) Very child-focused: It is not generalizable for musicians or educators.

b) No emotional awareness: It doesn't recognize or adapt to moods such as happy, sad or calm.

c) No feedback system: Kids can't rate on their learning, so the software cannot improve over time.

d) Not integrated with IoMusT ecosystems such as smart instruments and weables.

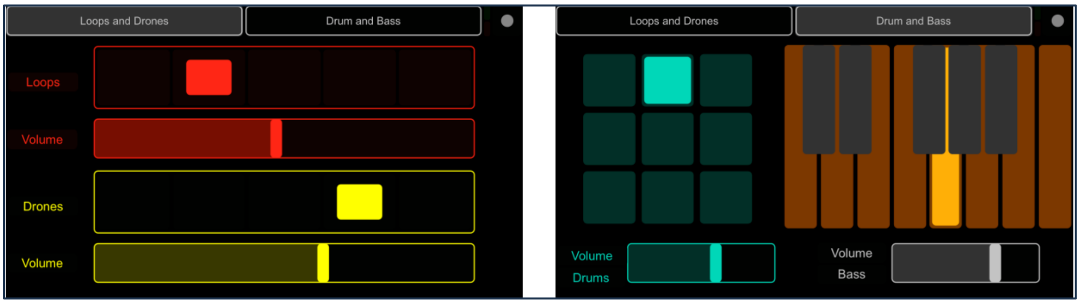

Fig.5 Interface of the Ubiquitous Smart Guitar system, enabling collaborative practice through mobile connectivity. An ubiquitous smart guitar system for collaborative musical practice Luca Turcheta and Mathieu Barthetb.

The *Ubiquitous Smart Guitar System* [Fig 5] introduced a prototype that combined smart guitar hardware with mobile applications in order to support collaborative music practice. This system successfully demonstrated how conventional instruments can be augmented with IoT-enabled features for enhanced learning and practice sessions. Nonetheless, the interface is highly specialized, focusing only on guitar practice and lacks a wider adaptability across different instruments, genres, and emotional contexts.

The interface shown above was developed as part of the ubiquitous smart musical instrument's framework. It provides musicians with interactive controls for loops, drones, drum, and bass layers using a tablet-like GUI. The design allows users to trigger sounds, adjust volumes, and combine instrumental elements in real time during performance or practice.

Strengths

a) Enables modular layering of sound elements (loops, drones, bass).
b) Provides an accessible touch-based control system linked with smart instruments.

Limitations

a) The interface remains focused on technical sound manipulation, not on emotional or pedagogical feedback.
b) It does not integrate semantic interoperability or support multi-user collaborative learning.

To highlight the freshness of the proposed model, it is necessary to compare it with previously available GUIs and IoMusT interfaces [Table 2]. Existing systems such as *Synth4Kids* and the *Ubiquitous Smart Guitar System* have provided us with valuable insights into music learning and collaborative practice, yet they still lack in terms of scope, adaptability, and emotional integration. These solutions no doubt technically profound and efficient but still lack to cater to the basic needs of music learners, teachers and community.

The proposed system in contrast emphasizes usability, emotion-awareness, multimodal integration, and real-time feedback through a simple GUI accessible to non-technical users. The following table summarizes the major differences between existing approaches and the proposed methodology.

Table 2: Differences between existing approaches and the proposed methodology

Feature	**Existing Interfaces**	**Proposed GUI**
User Focus	Designed for technical or researcher users	Targeted at non-technical musicians, learners, educators
Emotion Awareness	Not supported	Integrated through a user-friendly "Emotion Selector"
Feedback Mechanism	Absent	Includes immediate user feedback to refine future outputs
Accessibility	Often technical UI or complex visual Aping	Simplified, icon-driven navigation tailored for music users
Semantic Depth	Basic ontology querying or visual similarity mapping	Emotion-aware semantic modeling with intuitive visual support

DISCUSSION, LIMITATIONS & FUTURE DIRECTIONS

The past few years have witnessed growing incorporation of Semantic Web technologies, Artificial Intelligence (AI), and the Internet of Musical Things (IoMusT). Re-evaluating the existing research in this domain is important, as current efforts though being progressive in nature still fall short in achieving flawless integration across metadata modelling, infrastructure development, and intelligent music analysis.

6.1 Early Research (2014–2017)

Wilmering [1] was one of the earliest one's to investigate the Semantic Web technologies and their applications in music production workflow. His research depicted how RDF/OWL-based management of metadata could allow reproducibility and interoperability of workflows. Yet his work was converged to studio production, without covering the domains of IoMusT and user-driven creativity. With this as base, Gyrard et al. [2] suggested the M3 semantic engine for attaining interoperability between the different IoT domains. Although extremely useful for IoMusT, it was still generic in nature towards musical application.

6.2 Infrastructure Oriented Studies (2018–2020)

An edge-computing archetype for opportunistic crowdsensing in IoMusT was presented by Roy et al. [3], highlighting scalability and latency reduction. With a focus on energy efficiency, their later work DewMusic [5] , extended this paradigm into a dew–fog–cloud architecture for distributed processing of music data. The Semantic Web MIDI Tape, which Meroño-Peñuela et al. [4] proposed simultaneously, enriches MIDI files with linked data for more extensive contextual retrieval. Although infrastructure and symbolic enrichment were improved by these contributions but they still lacked in integration of emotional modelling and large-scale semantic interoperability.

6.3 Ontology Development and Adoption (2020–2023)

Exertions soon shifted towards developing ontological frameworks for IoMusT and related domains. Turchet et al. [6] established the population of the Smart Musical Instruments Ontology (SMI) with real-world data, while Marky et al. [7] worked with smart instrument sensors and HCI-based feedback to support solo learners. Turchet and Rottondi [8] later assessed the conceptual overlaps between Networked Music Performance, Ubiquitous Music, and IoMusT, proposing a semantic event-processing framework known as MUSEPA. Subsequent contributions included the Music Note Ontology [9], the Smart Musical Instruments Ontology [10] , and the Polifonia Ontology Network [11], each extending semantic modelling to symbolic notation, instrument descriptions, and cultural heritage. While these works improved formal representation and interoperability but they remained domain-specific in nature and lacked real-time adaptability.

6.4 Recent Advances (2023–2025)

A shift toward combining semantics with AI and user-friendly tools can be seen more in recent contributions. While Kantz et al. [13] presented OnSET, a toolkit that allows non-experts to explore ontologies without any technical knowledge of SPARQL, the Music Meta Ontology [12] tendered a flexible semantic model aimed at integrating heterogeneous music metadata. A semantic-aware interpretable multimodal auto-tagging model with the capability to integrate deep learning, ontology clustering, and multimodal fusion (audio, lyrics, metadata) was offered by Patakis et al. [14]. Though they still lack emotional awareness, cultural inclusivity, and full-scale IoMusT deployment, these advancements show promising steps towards the domain of explainability and multimodality.

6.5 Limitations

While this study highlights an intuitive, feedback-enabled, and emotion-aware interface for IoMusT, certain limitations still exist. First, the work is mainly conceptual and design-oriented, without a large-scale prototype or deployment in order to validate its real-world usability. The proposed GUI is illustrated using prototyping tools, which demonstrate feasibility but unable to capture the challenges of full implementation such as latency handling, scalability, or hardware integration. No doubt the aspect of emotional awareness is included but it is modelled in a simpler mode which makes it incapable for accounting complex cultural and contextual variations in music perception. Finally, integration with advanced IoMusT infrastructures such as ontology-driven interoperability and immersive technologies is still a domain left for future exploration.

6.6 Future Directions

While IoMusT research has advanced considerably, there are many areas that still remain unexplored. One important area that still remains is the development of integrated frameworks that have the capability to bring together semantic interoperability, real-time performance, and emotional modelling within a single system. Another unexplored sites can be referred to the fact of inculcating cultural inclusivity within our models so that we can explore wide variety of genres and musical practices across the whole world. The growing use of explainable AI and multimodal fusion techniques also promises making the process of music analysis and generation more transparent, adaptable, and reliable. Along with it there is a clear requirement for large-scale validation studies which involve both expert musicians and everyday learners, in order to better understand usability and long-term adoption. Finally, designing intuitive and feedback-oriented interfaces will be important to connect advanced back-end infrastructures with practical, user-friendly applications, which would allow IoMusT systems to move beyond prototypes and have a broader vision for real world use cases.

CONCLUSION & FUTURE SCOPE

This study examined the growth of the Internet of Musical Things (IoMusT) and pointed out various limitations in current systems which included their technical complexity, limited accessibility, and the absence of emotion-aware features. By emphasizing usability, multimodal interaction, and cultural inclusivity, the proposed system contributes towards making IoMusT more practical and meaningful in everyday use. This work can be expanded in a number of ways in the future. The creation of customized learning environments, where interaction and feedback change based on each user's progress, is one possibility. Another is the integration of immersive technologies such as AR and VR with the models that would allow more engaging forms of collaboration, performance, and teaching. There is also strong potential for IoMusT applications in the fields of healthcare and music-therapy particularly for supporting wellbeing and cognitive development through music. Exploring these areas of interest would help IoMusT move beyond experimental prototypes and establish itself as a widely adopted ecosystem with real social and cultural impact.

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