Hybrid Instrumentation Strategy in Balinese Gamelan Performances: The Challenge of Retaining Sonic Identity

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Abstract

Hybrid instrumentation is relatively uncommon in Balinese gamelan performance. Conventionally, gamelan is performed using a complete acoustic ensemble of approximately 30 instruments; however, contemporary performances often involve 12 instruments or fewer due to limitations in performer availability. Reductions in ensemble size can affect ensemble balance, textural density, and sonic coherence. The incorporation of digital technologies, resulting in hybrid acoustic-digital configurations, has emerged as a practical response to these constraints. Despite its relevance, scholarly discussion of hybrid instrumentation in Balinese gamelan is limited, particularly in relation to developments in performing arts practice and music technology. This study examines how digital and acoustic

instrumentation may be combined in Balinese gamelan performance while maintaining recognisable sonic features associated with established practice and cultural identity. Rather than proposing a fixed or prescriptive solution, it develops a practice-informed framework for hybrid performance. This framework considers instrumental roles, performer interaction, software mediation, sound equipment, and sound-engineering decisions in relation to the acoustic characteristics of performance spaces. Live performance is treated as the primary unit of analysis within a qualitative research design. Data generated through studio experimentation, simulation, and performance activity were complemented by interviews and literature. The study identifies three interrelated challenges in applying hybrid instrumentation: integrating digital technologies within established performance practices; maintaining Balinese gamelan sonic and cultural identity; and performers' capacity to realise compositions consistent with embodied playing techniques, ensemble interaction, and idiomatic gamelan practice. These findings offer considerations intended to inform future hybrid gamelan experimentation without prescribing a singular model.

Keywords: Balinese gamelan performance, digital-acoustic integration, hybrid instrumentation, practice-led research, sonic and cultural identity

Introduction

Digital technologies are developing rapidly. Across disciplines, there is a growing need to examine these developments carefully and to assess their broader social implications; the performing arts are no exception. In musical performance, digital technologies have reduced certain practical barriers and have made performance more accessible for some musicians. As these technologies have advanced, hybrid instrumentation has emerged as a solution in specific contexts, particularly where the availability of highly skilled performers is limited within competitive professional environments.

In this article, *hybrid instrumentation* denotes the combined use of digital and acoustic instruments in live performance. Digital instrumentation refers to technologies such as laptops, desktop computers, and dedicated devices that present musical material derived from recorded acoustic instruments or synthesised sounds, whereas acoustic instrumentation involves musicians performing directly on physical instruments. Hybrid instrumentation, as used here, therefore entails the simultaneous deployment of both domains in performance contexts where liveness is integral to artistic creation. By contrast, configurations that combine digital and acoustic elements solely for studio-based production (often described as "hybrid scoring" in soundtrack practices) fall outside the scope of this study, as live performance is not central to the creative process in such cases and occurs only incidentally, if at all.

Hybrid instrumentation has been adopted by some musicians as a strategy to improve performance outcomes and, at times, to enable more exploratory practice. Digital technologies can be used to produce strong instrumental sounds in support of performance quality (Heping & Bin, 2022; Horsburgh et al., 2015; Lin et al., 2016; Wang et al., 2024; Youngblood et al., 2021). This approach is more widespread in genres such as pop, jazz, rock, hip-hop, and other popular styles (Acosta Martínez & Daffern, 2023; Appert, 2016). In some situations, it is even common for a singer to

perform alone with digital support. In this sense, hybrid instrumentation is not new and has long been used to maintain or improve performance quality when resources for live playing are limited.

Within gamelan practice, particularly in traditional Balinese contexts, performers rarely consider this strategy, and existing research has not provided a definitive reason. One plausible concern relates to the sonic identity of the gamelan: there is an assumption that the acoustic character of gamelan sound is difficult to render when a composition or *gending* is performed with hybrid instrumentation. At the same time, this concern becomes a distinctive research challenge because many traditional gamelan performances do not use complete sets. Limitations in the availability of musicians often mean that a full set is not feasible. Although Balinese gamelan performance ideally uses around 30 acoustic instruments, performances sometimes use only part of a set (12 instruments or fewer), and this reduction in acoustic instrumentation inevitably affects the sound quality of the *gending*. For that reason, research on hybrid instrumentation in traditional performance is important not only in itself, but also for how it may shape future technological adaptation and improve efficiency when performer availability is limited.

Gamelan instruments are developed according to musical functions and performance purposes, both of which are inseparable from the settings in which performance takes place. When technological means are introduced, challenges vary by venue, as each has distinct acoustic properties. Open-air settings, traditional Balinese temples and stages, enclosed theatres, pavilions, and churches each present different soundscapes, with direct implications for sound engineering. These may include choices of microphones or speakers, adjustments to equipment placement, and the configuration of equalisation, filters, or effects. Musician monitoring and sound return are especially significant factors, and can strongly influence musicians' willingness to adopt hybrid instrumentation in performance.

Scholarship on Balinese gamelan has largely been framed through ethnomusicological and musicological perspectives. These include general accounts of the genre (McPhee, 2002), studies of Baleganjur Gamelan in *ngaben* ritual (Balkan, 2012), examinations of Balinese singing and performers' well-being (Reisnour, 2020), discussions of diversity through Gamelan Gong Gede (Hood, 2010), and analyses of Gong Kebyar as an expression of cultural identity (Roeder & Tenzer, 2012; Tenzer, 2011). Other studies address the commodification of Gamelan Slonding (Suharta, 2022) and questions of creativity in contemporary Balinese gamelan practice (Ardana & Consentta, 2022; Sudirana, 2020; Sudirga, 2020). A smaller body of work has examined sound-related dimensions of gamelan, including tuning systems and acoustic diversity. For example, studies by Sethares and Vitale (2023) on Balinese gamelan tunings and by Sugiarta et al. (2018) on comparative tuning techniques contribute to a more detailed understanding of tuning models and sonic variability, including the use of tools such as the Gamelan Tuning Explorer (GTE).

Although hybrid instrumentation has been discussed in a range of performance contexts, focused analysis of its use in Balinese gamelan is limited. In particular, existing research has not provided an integrated account of how such configurations might sustain Balinese gamelan cultural identity through pattern

design, performance strategies, and practices that support continuity within established musical and cultural frameworks. Building on this body of scholarship, the present study treats hybrid instrumentation as a means of examining cultural hybridity in contemporary Balinese gamelan practice. Rather than positioning hybridity as a break from tradition, it considers how hybrid methods function within established aesthetic and cultural logics, and how they relate to continuity, adaptation, and identity in performance.

The study seeks to identify patterns for the use of hybrid instrumentation in Balinese gamelan while retaining its acoustic and cultural characteristics. Sonic identity is examined through decisions concerning the allocation of digital and acoustic realisations, along with considerations of performer roles, software mediation, sound equipment, sound engineering, and venue acoustics. Sensory perception is used to assess the effectiveness of hybrid implementation and to inform a practice-oriented reference framework. Live performance experimentation is combined with analysis of selected hybrid performances to examine how these configurations may be employed without disrupting established performance conventions.

Although hybrid instrumentation is relatively uncommon in Balinese gamelan practice, its use raises important questions regarding future performance conditions. When carefully formulated, hybrid configurations may support practical efficiency in situations of reduced performer availability, while also contributing to wider discussions of hybridity in performing arts practice. In this study, hybrid instrumentation is therefore understood as a context-sensitive strategy for adaptation rather than as a substitute for traditional practice.

In this article, terms such as *sonic identity*, *idiomatic sound*, and *recognisability* refer to features commonly associated with Balinese gamelan practice, including beating effects related to *ngumbang/ngisep*, instrument timbres, and performance dynamics. These features are understood as practice-based and context-dependent rather than as fixed markers of authenticity. The analysis accordingly examines whether hybrid instrumentation can retain recognisable and culturally meaningful sonic characteristics within specific performance settings.

Methodology

Research Design

This study adopts a qualitative design grounded in a practice-led research approach. Practice-led research has an established international standing as a mode of inquiry in which knowledge is generated through artistic practice rather than through textual or empirical analysis alone (Meloni, 2021; Penny, 2014).

Within this framework, the practices examined are inseparable from artistic creativity. Creativity involves the development and transformation of concepts that can be examined systematically within research. Hockey (2003) describes this process in terms of creative identity and treats artistic practice itself as a site of knowledge production. From this perspective, creativity and knowledge are

mutually constitutive: artistic decisions and reflective processes generate knowledge, which in turn informs subsequent practice (Smith & Dean, 2009).

Unit of Analysis

The unit of analysis is a new Balinese gamelan composition performed on 21 September 2024 at Igreja da Misericórdia, a Roman Catholic church in Leiria, Portugal. Three musicians collaborated to create a new composition using a set of approximately 20 instruments. Some musical patterns were produced through digitally synthesised sound, analogue recordings of gamelan instruments, and live acoustic sound. The musicians worked through obstacles and challenges in developing the composition until it could be staged successfully. Notes made by the musicians during this process were also used as analytical material.

Data Collection Process

Practical materials were generated as core components of the composition, including a) the acoustic character of sound; b) musical patterns; c) processes of creating and interpreting musical patterns; and d) contextual evidence in the form of expert and audience perceptions used to evaluate sonic identity in relation to acoustic sound quality. These materials constitute the primary basis of analysis, while additional sources are treated as supplementary. Acoustic character, musical patterns, process, and perception are interrelated: compositional processes generate musical patterns with particular acoustic qualities, which are perceived and interpreted as expressions of sonic identity. Because these processes continually give rise to new challenges, they are treated as sources of knowledge within the study.

To address these analytical needs, the practice-led research was organised into three stages: collection, analysis, and conclusion. Materials were generated through studio work, simulation, and performance. Studio work involved creating representational patterns for both digital and acoustic instrumentation, including the design of musical material for each. During this stage, outputs for digital playback were recorded, and patterns for live acoustic performance were developed. Simulation involved combining recorded sound with acoustic instrumentation and functioned as an adjustment phase in which balance between recorded and live sounds was refined. Instrumentation choices shifted repeatedly through trial and error: some parts initially intended for acoustic performance were reassigned to digital playback, while others originally designed for digital playback were moved to acoustic performance. Simulation continued until an acceptable balance between digital and acoustic sounds was achieved.

Performance involved staging the composition in a live setting, where sound engineering played a critical role. Instrumentation solutions developed during simulation were reorganised and coordinated with the sound engineering team so that audience responses could inform whether the sonic balance was perceived as appropriate in performance. Perceptual and contextual materials were also gathered through interviews and a review of relevant literature. Interviews focused on audience perceptions of sonic identity and acoustic sound character, whereas the

literature review supported analysis of sonic identity and Balinese gamelan cultural identity.

Data Analysis

Analysis employed interpretive methods drawing on primary and secondary data and proceeded in two stages: description and interpretation. Description outlined recurring patterns, while interpretation assigned meaning to the analysed data (Braun & Clarke, 2006). This interpretive approach enables researchers to examine underlying meanings, document phenomena in detail, and consider broader implications (Denzin & Lincoln, 2018).

The analysis aimed to: a) examine challenges in musical processes that give rise to diverse patterns of sonic identity; b) explore relationships between sonic identity and Balinese gamelan cultural identity; and c) develop a working framework for hybrid instrumentation in Balinese gamelan performance. Analytical procedures included: a) mapping process data related to musical patterns, acoustics, perception, and cultural context; b) coding relevant primary and secondary data; and c) interpretive synthesis to deepen understanding of hybrid instrumentation formulation in Balinese gamelan performance.

Process analysis addressed studio work, simulation, and performance activities. Musical pattern analysis involved musicological description of recurring patterns. Acoustic analysis examined frequency spectra in digital and acoustic data using Cubase to read recorded waveforms. Although frequency and waveform comparisons supported assessments of balance, balance itself was evaluated through performance of compositions designed for hybrid instrumentation, as the process is empirical. Balanced sound between digital and acoustic components was treated as a requirement for sound integrity. Cultural perception and identity were examined through interpretation of audience statements concerning sonic identity as perceived in live performance and recordings. Concepts of sonic identity, mediation technology, hybrid culture, and cultural identity informed the analysis.

Results

Three challenges were central to the practice-led research process, which focused on developing a workable instrumentation framework for Balinese gamelan performance.

Challenges of Technology Integration

Technology integration refers to the performance of Balinese gamelan compositions using two forms of instrumentation, digital and acoustic, played simultaneously in balanced proportions. Each form of instrumentation presents musical patterns intended to produce a sound comparable to conventional traditional performances (full-set live performance), resulting in a live sound perceived as having qualities similar to those of typical Balinese gamelan performance. The practices undertaken are outlined below.

Practice One: Digital Capture, Loop Construction, and Compositional Arrangement

This practice involved recording musical patterns from several Balinese gamelan instruments for digital input into a computer. The instruments recorded were *ceng-ceng ricik*, *jublag*, *gangsa*, *kantil*, *tawa-tawa*, *kajar*, *klentong*, *kempur*, and gong. The recording process employed an audio interface (Behringer XAir 18), recording software (Cubase as a digital audio workstation and Zoom H4), and microphones (AKG C418, Zoom H4, Behringer C3, and Shure Beta 57A).

This process produced several musical patterns derived from the instruments listed above and was carried out using a desktop computer. Following this, sound looping was conducted by selecting outputs from multiple recording experiments so that the recorded sounds could be played repeatedly according to compositional needs. The sounds selected for looping were taken from the gong, *kempur*, *kajar*, and *kantil*. This process employed an audio interface (Behringer XAir 18), looping software (iZotope Breaktweaker), and editing software (Cubase as a digital audio workstation), again using a desktop computer.

The recorded and looped gamelan sounds were then arranged into a composition. This arrangement consisted of voices derived from the digitised gamelan instruments, with musical patterns written and organised through a digital audio workstation. The editing process used Cubase (DAW), Ozone Imager V2, and Neutron Elements and was carried out on a desktop computer.

The digitisation of these instruments was undertaken for several reasons. First, the gong, *kempur*, *klentong*, and *jublag* are low-pitched and function as colotomic markers. Second, the *kantil* serves as the second layer of ornamentation following the *gangsa*. Third, the *kajar* and *tawa-tawa* serve to maintain a simple tempo. Finally, the *ceng-ceng ricik* produces rhythmic patterns that are designed in a relatively simple manner. These musical functions were executed through digital means that were sufficient to produce stable, consistent, and predictable sounds while maintaining the accuracy of their musical roles.

Practice Two: Development of Acoustic Performance Layers

Practice two involved developing musical patterns for acoustic instruments (*suling*, *kendang*, *gangsa*, *reyong*, and *ceng-ceng ricik*) as media for live performance. These patterns provided ornamentation to the musical patterns used in the digital instrumentation, which had been recorded and looped through a digital audio workstation and could be played on demand via a computer. *Gangsa*, *kendang*, *suling*, and *reyong* were performed live over the digital layer. Examples of two musical patterns for *gangsa* and *reyong* are shown in Figure 1 below.

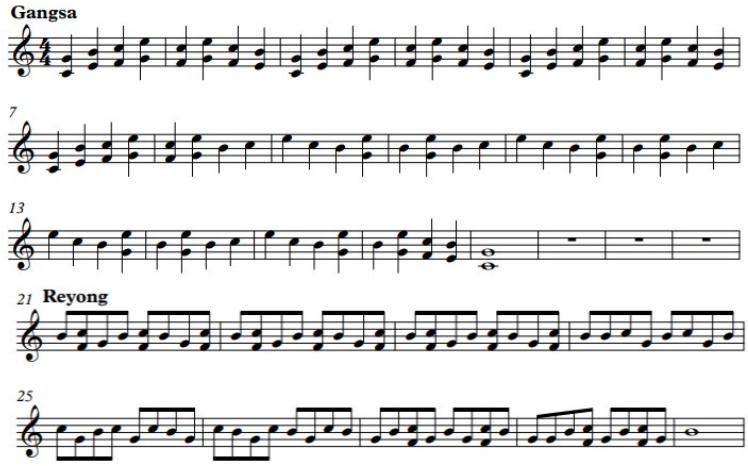

Figure 1. *Notation of* gangsa *and* reyong *for acoustic instrumentation.*

These instruments remained acoustic for several reasons. First, the *gangsa* carries the primary layer of ornamentation and provides dynamic variation that changes across a performance. Second, *reyong* patterns allow improvisation, and interaction between digital and acoustic parts responds to the acoustic conditions of the venue. Third, *kendang* patterns are structurally complex and require a high degree of musical sensitivity. Fourth, the *suling* has a melodic role and fills musical space and time during performance. Instruments that demand flexibility and continual adjustment to performance conditions are therefore better suited to acoustic performance.

Practice Three: Integration and Sound Balancing in Hybrid Performance

Practice three consisted of a try-out process that combined digital instrumentation sound and acoustic instrumentation within a single composition and performance. The central issue in this merging process was sound balance between the two forms of instrumentation. The most significant adjustments therefore concerned the acoustic quality of the digital instrumentation sound so that it blended with the acoustic instruments and was perceived by the audience as balanced and unified.

As described earlier, the adjustment process was iterative: both digital and acoustic parts were revised repeatedly until an appropriate balance was achieved. One example concerns the *kendang*. Initial *kendang* patterns sounded rough and failed to balance with the digital parts. Subsequent analysis showed that this roughness resulted from the use of a *panggul* (mallet) when playing the *kendang*. The revision therefore involved performing the *kendang* without a *panggul*.

In addition to changes in performance technique, some recorded patterns were also revised, including the *kantil* part. In this case, the digital pattern did not support a balanced result when the *kendang* was played with a *panggul*, and imbalance was likewise apparent when the relationship was reversed. Revisions

continued across both digital and acoustic components until the desired balance was achieved.

Challenges in Maintaining Sonic Identity in Hybrid Balinese Gamelan Performance

The central sonic principle addressed here is the beating effect characteristic of Balinese gamelan (sometimes described by musicians as a "wavy" sound) produced by slight tuning differences between paired instruments (*ngumbang*/*ngisep*). In hybrid performance, this effect must be preserved to maintain Balinese gamelan sonic identity. Its presence is assessed empirically through the simulation process, in which compositions designed for hybrid instrumentation are played and evaluated. Key sonic elements used as reference points in this assessment are summarised in Table 1, while the simulation process is pictured in Figure 2.

Table 1. *Elements contributing to the sonic identity of Balinese gamelan.*

Elements	Information
Ngumbang-ngisep	*Ngumbang-ngisep* is a foundational principle in Balinese gamelan sound and distinguishes it from other gamelan types. It is generally understood as an identity marker of Balinese gamelan.
Instrumental function	In instrument grouping, each instrument generally performs its musical function.
Timbre	The sound colour of *gangsa* is understood as an identifier of Balinese gamelan. Sound colour relates to spectral noise components and beating effects arising from paired tuning (*ngumbang*/*ngisep*).
Tempo	Tempo in Balinese gamelan *gending* is typically not slow and differs from much music globally. Tempo may vary substantially based on aesthetic considerations and musical patterning.
Dynamics	Dynamic shaping in performance is led primarily by acoustic instrumentation. *Kendang*, *suling*, and *gangsa*/*pemade* play key roles in controlling dynamic levels.

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Figure 2. Simulation process to obtain balanced sound through hybrid instrumentation combinations.

Challenges in Realising Composition within Idiomatic Performance Practice

In the hybrid instrumentation setting in Portugal, the three musicians assumed an additional responsibility: maintaining and adjusting the balance between digital and acoustic elements. As in other contexts, sound engineering mediates sound projection to the audience; however, hybrid settings introduce further variables. Unanticipated issues may arise, including noise, feedback, or imbalances in which one sonic layer dominates others. These conditions require performers to monitor and respond to changes in real time while continuing to engage in ensemble interaction. Figure 3 documents the hybrid performance context in Portugal through photographs and posters produced during the event.

Table 2 summarises the challenges identified during the hybrid instrumentation performance, particularly those affecting performers' capacity to realise the composition in ways consistent with established playing techniques, ensemble coordination, and idiomatic Balinese gamelan practice.

Figure 3. Posters (left) and photographs (right) documenting the hybrid instrumentation performance at the Igreja da Misericórdia, Leiria, Portugal in September 2024.

Table 2. *Performer-related challenges and required abilities affecting balanced sound in hybrid Balinese gamelan performance.*

Classification	Issue	Purpose	Description
Balance	Balance between the two instrumentations	Balance shapes the sound output perceived by the audience.	All instruments should be audible in proportion; no single sonic layer should dominate.
Balance	*Alternative 1*: Ability to listen to digital patterns through earphones and respond by playing acoustic patterns to adjust volume *Alternative 2*: Ability to listen to the combined output through the system output to judge balance	Sound is heard clearly; musicians respond by adjusting volume to achieve balanced and coherent ensemble sound.	This ability is situational, as staging conditions differ from rehearsal contexts. In repeated performances, volume levels are not guaranteed to match earlier settings. Musicians must remain sensitive to fluctuations in digitally generated sound.
Idiomatic Performance	Ability to realise musical patterns while simultaneously attending to digitally generated patterns	Musicians maintain expressive engagement while managing hybrid performance demands.	Performers must sustain two simultaneous attentional processes: monitoring digital–acoustic balance while remaining musically engaged. This dual focus presents a significant challenge.
Idiomatic Performance	Expressive shaping of musical patterns while coordinating with digital sound sources	Performances appear visually and musically dynamic.	Dynamic shaping is a key characteristic of Balinese gamelan performance. This expressive quality must be retained, even though hybrid instrumentation complicates performers' ability to sustain it.

Sound Perception

Sound perception refers to assessments by audience members and gamelan experts concerning the perceived sonic identity of gamelan sound. These assessments were gathered through interviews, supported by audio and video recordings. Two interview excerpts are presented below.

Interview 1:

Researchers:	Can you hear the sound of the j*ublag* in this video?
J:	Of course, I heard the sound of *jublag.* Is *jublag* an instrument that has a low sound?
Researchers:	That is right, can you hear the wavy sounds from the *jublag*?
J:	Yes, I heard wavy sounds from the *jublag*. I think the wavy sounds are clearly audible. At first, I thought the *jublag* was played acoustically, but it was played digitally.

Interview 2:

Researchers:	Can you tell us what instruments are played acoustically on this audio recording?
NP:	I do not know for sure, but I suspect the instruments played acoustically are *jublag, gangsa, suling, kendang,* and *ceng-ceng ricik.*
Researchers:	Not all of your answers are correct. *Jublag* is played digitally, and *ceng-ceng ricik* is played both acoustically and digitally.
NP:	Oh, I cannot tell for sure because the *jublag* and *ceng-ceng ricik* sound like they are being played acoustically.
Researchers:	What do you think of the sound balance of the show?
NP:	When I listen to the whole sound, between one instrument and the other, it is difficult to guess which instrument is played acoustically and which is played digitally. Therefore, in my opinion, the overall sound of the performance sounds authentic and balanced because I can still hear the wavy sounds of some instruments, such as *gangsa, jublag,* and *gong*, and all the instruments are clearly heard.
Researchers:	What do you think? What would happen if hybrid instrumentation were used for ritual performances? Would the community accept it?
NP:	I do not know exactly. Maybe you need to ask a specific community directly or try to hold a live ritual performance using hybrid instrumentation. However, my opinion is that the community should accept it normally. Why is that? Because my group usually plays gamelan for ritual ceremonies, and we often use gamelan with no full set. The sound of the gamelan is assisted by sound system equipment to make it clear. In addition, sometimes in the village, I only use music recordings to accompany ritual ceremonies.

The interview responses indicate that although the *jublag* was produced digitally, it was commonly perceived as acoustic; non-specialist listeners struggled to distinguish between digital and acoustic sound sources. Similar perceptual uncertainty was reported for instruments such as the gong and *ceng-ceng ricik*. These accounts show that the digital sounds closely approximated their acoustic counterparts, and participants therefore described the overall sonic identity as balanced and not readily separable into digital and acoustic layers. Rather than pointing to technical equivalence based on frequency comparison, the responses indicate that sonic identity is shaped primarily by auditory experience and holistic listener impression.

Discussion

Digital and Acoustic Integration as Technology Mediation

Technology integration is central to this research and is a determining factor in the viability of hybrid Balinese gamelan performance. Hybrid instrumentation requires deliberate technological adaptation. This requirement follows a broader recognition that developments in digital technology necessitate corresponding adjustments in musical resources to support sustainability (Leal-Rodríguez et al., 2023). In this context, the integration of digital and acoustic instrumentation operates through technological mediation, in which technology assumes a strategic role in shaping adaptive performance models for Balinese gamelan. As Tanner et al. (2017) note, digitalisation also influences cultural practice more broadly; for this reason, technological mediation holds particular significance in hybrid performance contexts.

Verbeek (2015) conceptualises mediation as the manner in which technologies shape both phenomena and human engagement with them, articulated through the notions of "instrumental realism" and "material hermeneutics." From this perspective, technology is not neutral but actively conditions how phenomena are encountered and understood. In the present study, hybrid instrumentation employs tools such as the Behringer XAir 18, Cubase (DAW), iZotope Breaktweaker, and related software as mediating instruments. When Cubase is used to analyse acoustic spectra, it mediates users' understanding of acoustic phenomena by rendering frequency information visible. This process relies on users' baseline knowledge of Balinese gamelan tuning systems across digital and acoustic domains, whereas evaluative judgement remains empirical. Frequency records therefore inform assessments of whether hybrid integration preserves instrument-specific sonic identity.

Aside from mediation, digital-acoustic integration introduces gains in efficiency, accuracy, and flexibility. Hybrid instrumentation enables performances to realise extensive sonic resources despite limited personnel, with digital instrumentation providing a virtual space for presenting musical parts while retaining instrumental character. Recording techniques further allow controlled modification of sound qualities. During the performance in September 2024 in Portugal, sounds associated with *jublag*, *ceng-ceng ricik*, *kajar*, *klentong*, *kempur*, gong, *kendang*, *suling*, *gangsa*, and *kantil* were realised, while only three musicians performed multiple instruments live. This configuration illustrates how hybrid instrumentation can address practical limitations without compromising ensemble coherence. In parallel, hybrid setups permit flexible manipulation of sound colour and patterning, which allows richer textures and sustained harmonic balance even with reduced performance forces.

Balinese Gamelan Sonic and Cultural Identity

Sonic Identity

Sonic identity is a necessary condition for Balinese gamelan to be recognised as such. Recognition rests on characteristic sonic features that distinguish this tradition from other forms of gamelan. Central to this identity is the combined effect of *pengumbang* and *pengisep* frequencies in each instrument bar (Paelinck et al., 2006; Sugiarta et al., 2018; Vitale & Sethares, 2021). *Pengumbang* and *pengisep* refer to paired bars that function together to produce a single tone, a principle applied across pitch levels. This pairing constitutes a core aesthetic element of Balinese practice (Bandem, 1986; Sukerta, 2012).

Technical studies commonly examine *pengumbang-pengisep* relationships using electronic tuners, frequency and spectrum analysers, and related digital tools that enable mathematical analysis. In this study, sonic identity in a hybrid context was examined through a combined approach: technical analysis using Cubase in conjunction with auditory evaluation by audiences and experts. This approach integrates quantitative measurement with listening-based judgement and retains auditory evaluation as an established means of assessing gamelan sound within performance practice.

Sonic identity in hybrid performance is further informed by sound theory. Rossing et al. (2001) describes sound preservation in terms of maintaining sound characteristics from source to listener, with frequency spectrum, envelope, and wave phase as key components. From this perspective, sound should retain its spectral and temporal characteristics as closely as possible to the source when recorded, amplified, or replayed, even though minor variation does not necessarily negate sonic identity. From a different standpoint, Kivy (1995) argues that sound identity may be assessed through both frequency relationships and compositional context. This assessment concerns whether a performance resembles the sound associated with a work at the time of its creation and distinguishes between acoustic similarity and compositional similarity.

In this study, the “wavy” sound produced by *pengumbang-pengisep* pairing (that is, the beating effect) was retained in its characteristic form. The perception of sonic identity is also shaped by performance venue. The Igreja da Misericórdia in Leiria possesses acoustic properties that prolong resonance, a feature consistent with the vibrational qualities associated with Balinese gamelan. This acoustic environment supports the perception of hybrid instrumentation as Balinese gamelan, even when presented outside its customary setting. Continuity is further reinforced through compositional features, particularly the use of *kekebyaran* motifs, which contribute to a recognisable sonic character. Sonic identity in this context emerges through the interaction of sound production, acoustic setting, and listener perception, rather than through any single parameter.

Cultural Identity

Balinese gamelan may be recognised as Balinese when its sonic identity is articulated through the *pengumbang-pengisep* pairing. Such recognition does not depend on a fixed or essentialised conception of identity, but on sonic features that acquire meaning through practice and perception. As Stuart Hall (1990) argues, cultural identity is not static but continually formed and re-formed through representation and shared understanding. From this perspective, sonic identity functions as a cultural marker that takes shape through ongoing musical practice rather than as an intrinsic or immutable property.

Within this framework, technological adaptation through hybrid instrumentation becomes part of identity formation and reconstruction, as technology influences how communities express, sustain, and transform cultural identity. In contexts of technological development, cultural expression and maintenance involve heightened awareness of identity (Fu, 2024). When hybrid instrumentation is applied to Balinese gamelan performance, the sonic features that are retained or selectively foregrounded function as representations of cultural identity (Hu et al., 2024). At the same time, the practical implementation of hybrid systems presents distinct challenges.

Hybridity involves processes of cultural interaction shaped by migration and intercultural contact. Culture, from this perspective, is not given in advance but emerges through interaction and the recombination of elements from different contexts, producing identities that remain dynamic and open to negotiation. Cultural identity is therefore open-ended, with diversity and transformation constituting conditions of cultural formation rather than deviations from it (Hall, 1990). Within hybrid processes, identity does not disappear; it persists through the recognisability of key elements and practices. Continuity depends not on purity or fixity, but on the capacity to sustain recognisable features while accommodating change through adaptive practice, reinterpretation, and innovation (Hall, 1990).

In Balinese gamelan, cultural identity is articulated through sound, and sonic features therefore play a central role in how the tradition is recognised and understood. A primary marker of this identity lies in the *pengumbang-pengisep* pairing, which produces the distinctive “wavy” sound associated with the tradition. This quality constitutes a core sonic characteristic (Sukerta et al., 2019). Compositional parameters including timbre, harmonic relationships, tempo, and dynamics further contribute to sonic identity (Putra et al., 2020). Timbre and harmony vary widely, and digital tools can extend this variation through static or contrasting patterns, which enhance textural density and dynamism.These qualities correspond with descriptions of Balinese gamelan as energetic and forceful (Sukerta, 2009).

Tempo presents greater difficulty in hybrid contexts. Sudden tempo and dynamic changes are harder to realise when digital instrumentation depends on metronomic control. In this study, performance tempo therefore remained relatively constant. Hybrid instrumentation thus preserves key elements through which cultural identity is sonically articulated, while imposing limits on the realisation of certain performance characteristics.

Idiomatic Balinese Gamelan Performance in Hybrid Contexts

Presenting Balinese gamelan through combined digital and acoustic instrumentation poses significant challenges because the two media operate according to different performance logics. Digital instrumentation is typically scalable and temporally fixed, whereas acoustic gamelan performance is characterised by flexibility shaped through musicians' experience, sensitivity, and ensemble interaction. Fixity reflects the mechanical properties of digital systems, while acoustic flexibility arises from embodied performance knowledge. Although distinct, these characteristics may be productively combined when composers and musicians engage carefully with processes of integration. For this reason, achieving an idiomatic gamelan performance within hybrid instrumentation places considerable demands on both composers and performers.

Compact and responsive interaction among musicians constitutes a central challenge in this context. Ensemble cohesion depends on each player's attentiveness to the actions of others and the ability to respond in ways that sustain expressive continuity. Visual communication supports ensemble coordination through gestural cues in melodic playing, rhythmic coordination, and dynamic control. These forms of expression are fundamental to Balinese gamelan performance and are often described through metaphors of wave motion at sea and the movement of kites in the air. Waves rise and fall, briefly disturbing and then stabilising the surface, while kites shift direction through coordinated movement with their trailing forms. These images evoke patterned motion, balance, and directional coherence. Expressive interaction thus operates as a source of order and cohesion in Balinese gamelan performance and constitutes an important dimension of its cultural identity.

In hybrid performance settings, musicians attend not only to one another's gestures but also to graphic representations and sonic cues generated by computer systems. Performers are therefore required to respond sensitively to digitally mediated sounds in order to maintain ensemble balance and preserve the sonic identity of the music. However, auditory experiences developed during simulation often differ from those encountered in live performance. This discrepancy arises because simulation environments do not fully replicate performance conditions, particularly when additional microphones and sound reinforcement systems are introduced during live presentation. In such situations, musicians' adaptive responsiveness becomes critical. These observations indicate that hybrid Balinese gamelan performance is highly situational, with certain decisions, for instance, balance and volume, becoming clear only during performance itself. As a result, effective realisation depends strongly on performers' experience, sensitivity, and capacity to respond to changing performance conditions.

Conclusion

This study demonstrates that hybrid instrumentation in Balinese gamelan performance modifies established performance procedures and playing techniques through which musicians articulate and sustain ensemble sonic identity. These modifications show that hybrid configurations can offer practical gains in efficiency

and flexibility, particularly under conditions of limited performer availability, while still enabling gamelan performance to take place. Nevertheless, hybrid instrumentation entails shifts in musical identity, as processes of hybridity necessarily involve reconfiguration rather than simple substitution. The findings therefore draw attention to the need for sustained and critical attention to the ways in which digital technologies are introduced, managed, and evaluated in relation to Balinese gamelan cultural identity.

The principal contribution of this research lies in its examination of how hybrid instrumentation shapes artistic practice at the level of performance. By combining technical analysis with practice-led experimentation and perceptual assessment, the study offers a framework for understanding interactions between digital and acoustic resources in gamelan contexts, an area that remains underexplored in existing scholarship. Beyond its analytical contribution, the study provides practical insight into the conditions under which hybrid instrumentation may function effectively in performance, with implications for performers, educators, and researchers concerned with technologically mediated musical practice.

The scope of this research is necessarily limited by its focus on a single case study. As such, it does not claim to represent the full range of hybrid practices or cultural responses within Balinese gamelan traditions. Nor does it address in depth questions of community reception and ritual acceptance, which require broader ethnographic engagement. Further research might therefore extend this inquiry across multiple performance contexts, ensemble types, and cultural settings in order to examine how hybrid instrumentation is negotiated within different social, aesthetic, and ceremonial frameworks.

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