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Augmenting musical instruments with digital identities

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ABSTRACT

We explore how augmenting musical instruments with digital identities can enhance their provenance, utility during creative practice, and personal meaning. A literature review reveals the importance of object identities in general and instrument identities in particular, how the identities of things can be digitally augmented, but also that this idea has not been widely applied to musical instruments. A first case study draws on interviews to illuminate the current practice of physically relicing guitars to enhance their identities. A second case study of augmenting a guitar to capture and retell its life story illuminates potential digital identity practices. Reflecting on both case studies, we reconsider musical instruments as product-service systems in which physical instruments come bundled with digital services that forge, perform, and share their identities.

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Augmented instruments; digital identities; provenance; relicing; product-service system

Introduction

The idea that musical instruments have identities that add meaning and value to them is commonplace among players, collectors, and the wider music industry. Some instruments become individually identifiable through their longevity and associations with famous musicians, but even everyday instruments can tell meaningful stories to their owners. This is especially true of the guitar, which appears to have acquired a particular cultural status among the wider public (Dawes, 2016), and whose myriad designs, often recreated as replicas, and even artificial relics, typically embody a recognisable and distinct sense of identity.

This paper builds on the idea that the identities of musical instruments are important to establishing their provenance, supporting their utility, enhancing their performativity, and reinforcing personal connections with the musicians who play them. It also explores the vital role digital technologies can play in building such identities and invoking them in various situations. Many people maintain digital identities, online projections of themselves which may be visible (e.g. on social media) or invisible (through the digital traces left behind as they negotiate various online services) (Beck, 2015). Might musical instruments also have digital identities, both visible and invisible, and how might these enhance their utility, meaning, and value?

In what follows, we explore diverse ways in which musical instruments might be augmented with digital identities, a focus that we claim is not only important, but that differs from much prior research on digitally augmenting musical instruments that has tended to address their direct sound making capabilities. While making sound is undeniably important, we argue that so is reinforcing the identities of instruments, a fact that is clearly not lost on their manufacturers as we reveal below.

Taking the guitar as our example, we make our case by triangulating three distinct contributions. First, we review the wider literature on object and instrument identities, and the role of various digital technologies in supporting these, to establish foundational ideas. Next, we present an interview study with guitarists that reveals important aspects of guitar ownership, especially their thoughts about and engagement with the controversial practice of relicing in which new guitars are deliberately distressed in the workshop with a patina of wear and tear to strengthen their apparent identities. Finally, we present a Research Through Design (Zimmerman & Forlizzi, 2014; Gaver, 2012) case study in which we digitally augmented a guitar to capture and retell its life story as it passed among players, reflecting on how this established a unique and rich identity over eight years.

In discussing these two case studies, we reconsider musical instruments to be product-service systems

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(Smith et al., 2014) in which physical instruments come bundled with digital identity services that support provenance, learning, performing, recording, personal meaning making, and tinkering, modding and making. We argue that the identities of instruments need to be jointly forged by both manufacturers and owners through both physical and digital practices, and that they also need to be performed, by which we mean directly invoked during creative practice with the instrument to hand. We also consider the sharing of instrument identities in which instances of instruments share stories with others, including at transitions of ownership when they are traded or passed on.

Related work

We review related work in four parts. In part one, we briefly turn to the wider literature beyond computer music research to distil foundational concepts about the identities of everyday things. We then review previous literature, both fictional and academic, that speaks to the importance of musical instruments having distinct identities. Following this, we review previous projects that have explored how digital identities can augment the identities of everyday things. Finally, we consider how various digital technologies have been previously applied to augment musical instruments, which overwhelmingly addresses their sound making capabilities rather than their identities, identifying the research gap addressed by our paper.

The identities of everyday things

The identities of material things have fascinated scholars for millennia, from the ancient Greek philosophers who debated the paradox of Theseus'Ship[1], to Heidegger's (1971) assertion that objects become noticeable things in the moments when they wear out and so are brought to our attention in new ways, to many others besides. Discussions of materiality and identity are to be found in many disciplines across the arts, humanities, social sciences and beyond.

To ground our paper, we begin by considering how the identities of everyday things emerge throughout their lifelong careers and social lives. In his influential work 'The Social Lives of Things' (1986), the anthropologist Arran Appadurai first introduced the 'conceit' that *commodities* (products that are socially exchanged, including for money – musical instruments in our case) have complex social lives. He subsequently applied this idea to the analysis of art works as cultural commodities and in his essay 'The Thing Itself' (2006), Appadurai's work highlights three important perspectives for our paper. First, is that objects follow careers over their lifetimes which may involve them moving back and forth between being exchangeable commodities and not: 'Thus, today's gift is tomorrow's commodity, yesterday's commodity is tomorrow's found art object, today's art object is tomorrow's junk, and yesterday's junk is tomorrow's heirloom' (Appadurai, 2006). He proposes that art works 'congeal' at points along their careers through 'a momentary assemblage of mobile persons and things' (Appadurai, 2006). Second, he separates homogenous from singular commodities, the former being standardised commodities that are indistinguishable within a class, while the latter are uniquely identifiable instances. He notes that 'any and all things can make the journey from commodity to singularity and back'. Third, is to recognise that commodities acquire and distribute knowledge throughout their careers; knowledge that arises in both their production and appropriate consumption, and that 'whenever there are discontinuities in the knowledge that accompanies the movement of commodities, problems involving authenticity and expertise enter the picture' (Appadurai, 1988).

The identities of musical instruments

The idea that things have social lives has been applied to musical instruments. This is a recognisable trope in literature. The central protagonist of Annie Proulx's novel Accordion Crimes (2007) is a green button accordion that tells the stories of generations of owners as it passes through their hands. In a similar vein, Francois Girad's 1998 movie The Red Violin (1998) recounts the career of a unique violin, painted with human blood, that spans hundreds of years and brings tragedy to those that own and play it (see Longfellow, 2001). Such examples illustrate the compelling idea that instruments have identities, careers and even agency that extend beyond and connect the lives of individual humans.

Turning to the academic literature, the musicologist Eliot Bates has written about the social life of musical instruments (2012). Illustrated by the example of the saz, a common instrument among people of Anatolian, South Caucasian, and South-eastern European ethnicities, he explores the relationship between musical instruments materiality, song, body, nation, and image. He concludes that musical instruments have agency and that much of their mystique and allure is 'inextricable from the myriad situations where instruments are entangled in webs

[1] The Ship of Theseus that carried the hero Theseus and the youth of Athens home from battle in Crete and was preserved and displayed in Athens' harbour over centuries, during which time the original rotting timbers were gradually replaced by new stronger ones. This provoked Greek philosophers to debate the question of whether the ship on display could be considered to be the same one that had returned from Crete many years before?

of complex relationships – between humans and objects, between humans and humans, and between objects and other objects', noting how musical instruments are constitutive of social interaction not just incidental to it, and raising the question of 'whether the performer performs the instrument or the other way around?'. David Byrne (2012) provides examples of this musical catch, in which instruments are the subject of performances rather than the object:

> Organs, for example, emerged from liturgical music . . . they play Western scales and tuning easily, and anything else with great difficulty. You press a key on these instruments and you're automatically in the world of Western music—no variations of pitch or bending of notes is possible (Byrne, 2012).

Equally, but in contrast to the inherent limitations of a musical instrument, technological advances have also given agency to musical innovations:

> The electric guitar still privileged Western scales … but the sounds you could get from an amplified instrument were almost limitless. Piano-like plunks, percussive scratchy chords, saxophone-like rasps, and gamelan-like bell tones. … as a result, texture and tonal quality increasingly became part of composition (Byrne, 2012).

Further emphasis on the agency of artefacts can be found in Bruno Latour's (alias Johnson, 1988) seminal essay on the 'sociology of the door closer' which – despite its focus on more mundane technologies than musical instruments – discusses, amongst other things, the ways in which everyday objects – depending on their role within human-object interaction – can shape our social lives, and even be anthropomorphised and given distinctive identities. Of all instruments, it is modern guitars that appear particularly prone to acquiring distinctive identities, as a result of their prominent role in popular music from much of the twentieth century onwards. Popular culture abounds with stories of recognisable guitars, from renowned brands to individually famous instruments, accounts of which can be found in numerous guitar magazines and coffee table books, while examples are exhibited in specialised guitar museums worldwide and at venues and cafes (most notably the Hard Rock Café franchise). Kevin Dawe's (2016) wide-ranging account of the 'New Guitarscape' adopts a critical theory perspective on the guitar as an immensely popular large-scale musical-cultural-social occurrence. He looks far beyond its material and acoustic qualities as might typically be considered by the field of organology, to instead explore the instrument's wider cultural and social impact. He repeatedly draws attention to the importance of guitar identity, noting how guitars are brought to life and imbued with character by manufacturers through distinctive named designs and finishes and associations with celebrity players, and how such identities become personalised and extended as instruments subsequently pass among players. He considers how the guitar's extensive presence on the Internet and in popular computer games serves to spread guitar culture globally and considers the concept of the virtual guitar.

The guitar industry attempts to imbue newly made guitars with identities in various ways, including the production of replica instruments, encompassing reissues, celebrity endorsements, and the controversial technique of relicing – systematically distressing new guitars in the factory to give them a patina of wear and tear (Figure 1).

For example, Fender's Custom Shop offers a choice of reliced products, each with an imagined history of its ownership and use (Guitarist, 2020):

N.O.S. (New Old Stock)	A vintage replica 'As if you bought it new—in 1954'.
Closet Classic	Slightly tarnished as if 'kept in a case most of its life—perhaps even forgotten'.
Journeyman Relic	A tarnished finish with added 'down-to-the-wood nicks and dings … … and moderate playing wear'.
Relic	Finished with 'authentic worn-in wear of a guitar that has experienced many years of regular use in clubs and bars. Marks that tell a story'.

Articles and letters in the guitar press and postings on guitar forums reveal relicing to be a controversial practice. For some, it produces desirable objects that they couldn't otherwise afford given the increasing rarity of genuine road-worn instruments, but for others, owning and playing a reliced guitar is disingenuous, projecting a fake affectation of a performing artist who has literally 'played the paint off their instrument' (Bohlinger, 2013).

In terms of academic studies, Fernandez and Lastovicka's (2011) interviews with the owners of replica guitars reveal how they value them for their associations with famous players which they perceive transfers to their own playing. The authors view replica guitars through the analytic lens of fetish objects – magical objects of extraordinary power and influence – that carry with them the identities of famous musicians that then become invoked through 'everyday magical thinking'.

In contrast, Pinch and Reinecke's (2009) interviews with musicians who acquire and use vintage and retro equipment, including reliced guitars, reveals that they may be in search of a distinctive sound, which often involves extensive collecting and experimentation through tinkering, twiddling, and tweaking old gear. They introduce the concept of 'technolostalgia' in which musicians move beyond conventional nostalgia (a desired return to an ideal past in response to a troubled present) to instead user vintage instruments to invoke connections to the past to make the music of the present.

Figure 1. Two distinct levels of guitar relicing. Left: A lighter 'road worn' style of relicing with some paint and lacquer wear and tarnished metal work[9] Right: A heavy relic style with significant paint wear, rusty metal work and dirty volume and tone knobs (note the lack of wear patterns and dirt on the fretboard compared to the guitar body)[10]

While seemingly contrasting, these two perspectives can both be true – owners may value replica instruments both for their perceived associations with the auras of famous players and for bringing vintage tone to contemporary music.

A recognised aspect of guitar identity that is widely seen as important concerns provenance. While relevant to trading of guitars, especially second-hand ones, this has come to the fore due to environmental legislation that governs the import and export of endangered species, including tone woods that are prized by guitar makers. Gibson and Warren's (2021) inquiries into the guitar making industry encompasses guitar manufacturing from the sawmill to the factory, revealing tensions between ecological and cultural concerns, small scale sustainable vs industrial scale wood manufacture, and industrial scale manufacturing and methods. Furlett (2015) reviews the impact of the international Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) act and of the associated US Lacey act on the guitar industry, describing two government raids on the Gibson company and the risk of confiscation and destruction of vintage instruments when attempting to cross borders. They highlight serious flaws with the current guitar passport scheme that emerged from the COP16 climate conference that requires owners to provide:

> The scientific and common name of each plant or animal component of the instrument; a description, including metric weight, of the instrument; date of manufacture; date of acquisition with appropriate documentation, for example, a bill of sale, United States Customers import declaration, or transfer documents; the current location of the instrument; the purpose of the export, whether for personal, display, competition, performance, or other use.

They propose a revised passport scheme alongside 'simplifying border crossing with musical instruments, preventing criminal liability from attaching to unsuspecting musicians, and protecting the environment by preventing illegally sourced wood products from entering the marketplace'. Greenberg (2016) notes how the challenge of guitar provenance reaches back as far as documenting wood at the point of harvest, requiring a system that can track 'track wood from logs to guitars. We note here an

[9] Photo by Abdo alshreef: https://www.pexels.com/photo/guitar-18676286/

[10] Photo by irish10567 from Little Falls, NJ, USA (https://commons. wikimedia.org/wiki/File:Fender_Road_Worn_50s_relic_Stratocaster_(200 9-01-17_08.54.55_by_irish10567).jpg), https://creativecommons.org/licenses/by/2.0/legalcode

interesting parallel to the paradox of Theseus' ship noted earlier, with the identities of guitars breaking down into the individual planks of wood from which they are made.

The digital identities of everyday things

From the widespread adoption of social media that capture and share stories about the lives of billions of people worldwide to the use of wearable sensors to capture and reflect on physiological data as part of the 'quantified self' (Lupton, 2016), digital technologies have a powerful role to play in the constructing identity. Just as people acquire digital footprints throughout their lives that underpin their increasingly digital identities, so do objects.

Multiple projects have explored how digital technologies can enhance the identities of everyday things. The Significant Objects project purchased 100 insignificant objects costing little over one US dollar each on average at flea markets, yard sales and thrift stores, recruited storytellers to write fictional histories about them, and then readvertised them online, alongside the stories on eBay (Glenn & Walker, 2012). The objects now sold for over 2000 percent of the original purchase price, demonstrating the power of such stories (albeit professionally written ones in this case) to transform insignificant objects into significant ones and in so doing, to greatly enhance their value. The Tales of Things and Electronic Memory (TOTeM) project (Barthel et al., 2013) employed a combination of RFID, QR Code and Web technologies to augment physical things with stories of prior use, most notably second-hand items in charity shops that, unusually, could be interrogated to reveal their previous history, showing that there is also value to be gained by associating more personal and everyday stories with physical objects (De Jode et al., 2011).

Melo (Orth et al., 2020) was a bespoke music player in which four material objects representing specific life stories/identity narratives could be placed on a stand and triggered (via RFID) to play music connected to these stories. Their findings demonstrated that these physical-digital associations increased the likelihood of assigning personal meaning to the material products. Finally, an ethnographic study of making, decorating, and playing with wargaming miniatures revealed members' practices for documenting and sharing their crafting methods within a community alongside the capture of 'data' (e.g. battle statistics) about the lives of individual objects that emerged as being significant through their use (Darzentas et al., 2015).

While these examples demonstrate the value prospects for attaching identities and meaning to objects through digital means, studies of hybrid gifting – the coupling of physical and digital artefacts in the exchange of gifts – reveals tensions in physical-digital associations. In Kwon et al.'s (2017) studies, participants placed less meaningful value on the digital component of a hybrid gift compared to the physical counterpart, and Spence et al. (2023) demonstrated that the meaningfulness is largely perceived to be 'grounded' in the physical gift while the balance of digital value is contextually dependent. These findings are echoed in consumer research that identifies psychological ownership as the driver for lower consumer valuations of digital goods compared to physical, for example souvenirs or media (Atasoy & Morewedge, 2018). However, Mardon et al. (2023) note the imprudence of generalising this assumption – for example digital only objects in gaming or an email kept for posterity can be considered highly valuable – and call for better alignment of the affordances of digital objects and services with consumer expectations to enable the development of more meaningful and possess-able digital objects.

Digitally augmenting musical instruments

There is a long-established history of applying digital technologies to enhance musical instruments, both to create new Digital Musical Instruments and to augment more traditional ones. The *New Instruments for Musical Expression (NIME)* conference series reflects the breadth of interest in this field and the plethora of available approaches. Perhaps due to its popularity and flexibility, the guitar is seen as a 'laboratory for experimentation' by San Juan (2020). In the case of the guitar and other handheld string instruments such as violins and mandolins, instrument designers have explored various approaches to augmenting instruments including mounting additional controls in the surface of the instrument (MacConnell et al., 2013; Turchet, 2017; Ko & Oehlberg, 2020) and focusing on proxy artefacts associated with the instrument, for example the guitar plectrum (Vets et al., 2017; Morreale et al., 2019), vibrato bar (Kristoffersen & Engum, 2018), or violin bow (Young, 2002). Understandably, the focus of much of this research has been on extending the sonic capabilities and real-time interactional possibilities of musical instruments, that is the ability to produce sound that lies at the heart of musical practice, and often in a way that does not compromise hard-won musical skills and established musical practices.

In recent years the guitar industry has begun to innovate digital services that can be viewed as enhancing the identities of instruments in various ways. Fender Musical Instruments have introduced various online and digital app services that integrate into the ecosystem of guitar

ownership including *Find Your Fender*[2] an interactive website to help orient potential new customers to the range of products they offer; the *Fender Play*[3] guitar teaching service; and the *Fender Mod Shop*[4] service that enables customers to design and configure the purchase of a new personalised instrument. The digital technology that underpins sound processing in modern guitar amplifiers and audio effect processing surfaces further opportunities for the creation of identity. Notable here are algorithms that model the sounds of vintage vacuum tube amplifiers. Guitar effect manufacture TC Electronics, for example, have their TonePrint system[5] in which parameter settings of their effects pedals can be configured directly via an accompanying app, saved and shared. And of course, you can download effects settings configured by your favourite players. Neural DSP's *Quad Cortex*[6] is supported by their *CortexCloud* service for storing, transferring, and sharing user's amplifier settings amongst their community.

Despite these commercial developments, relatively little has been written in the research literature about the use of digital technologies to enhance the *identities* of instruments with a few notable exceptions. Turchet et al. (2018) set out a broad vision of The Internet of Musical Things that connects smart instruments with other smart devices to support a range of musician – musician, audience – musicians, and audience – audience interactions, through applications including: augmented and immersive concert experiences, audience participation, remote rehearsals, music e-learning, and smart studio production. In their view, smart instruments can be augmented and connected to support a wide variety of services beyond sound generation, for example affecting the lighting system in a music venue or recommending songs to a musician for learning. In describing the creative exploratory processes of musicians who engaged with the D-Box, a deliberately hackable digital musical instrument, McPherson et al. (2016) note the idea that such instruments might enable musicians to save and retrieve useful new hacks as part of their histories of use and to share them with others. A quite different exploration of the identity of musical instruments in relation to digital technologies is reported by Harrison et al. (2018) who considered the question of what makes an instrument recognisable as a being guitar? They report a study of four guitar-derivative digital musical instruments that varied according to their global form (guitar-like body versus a tabletop enclosure) and control mechanism (physical strings versus touch sensors). They report a slight preference for the technical familiarity of the stringed instrument among experienced guitarists, whereas non-musicians tended to prefer the touch guitar instrument, perhaps due to the relative ease of use of the touch sensor or maybe the cultural associations of the recognisable guitar form. Much like short-lived hybrid musical instrument designs, such as the 1970s 'Guitorgan' that combined electric organ circuitry controlled through a guitar fret board; or the 1980s 'keytars' designed to give keyboardist the same performative freedoms on stage as guitarists, these studies indicate a prerequisite for exploring hybridisation prospects for traditional form instruments that extend beyond sonic and performative capabilities.

Summary of related work

To summarise our review of related work, prior research from across various disciplines suggests that everyday things in general, musical instruments, and especially guitars, can usefully be viewed as having identities that develop as they pass through different hands, and that can enhance their value, meaning and use. It also reveals how current industry practices around replica guitars strive to imbue instruments with identities during their manufacture. A second body of work considers how digital technologies can augment the identities of everyday things, enabling them to tell stories about their histories of past ownership and use. However, it also reveals that, despite the emergence of digital services for choosing and customising guitars and for sharing sounds among digital effects and amplifiers, such ideas have not yet been widely considered by those researching future musical instruments, whose work has tended to focus on augmenting their real-time sonic and interactional possibilities. This is the research gap addressed by our paper – the opportunity for computing technologies to enhance the digital identities of musical instruments and so add value to them in various ways beyond their immediate capabilities for musical expression.

The following sections present the two case studies that help us address this gap, the first deepening our understanding of current identity practices, most notably the controversial idea of relicing, and the second reflecting on ten years' experience of constructing the digital identity of one guitar.

Case study one: the practice of 'Relicing' guitars to give identities

Our first study explored how guitars currently come to acquire identities, focusing on the practice of relicing

[2] https://www.fender.com/findyourfender?locale = en-GB
[3] https://www.fender.com/play
[4] https://www.fender.com/en-GB/mod-shop.html
[5] https://www.tcelectronic.com/tonePrints.html
[6] https://neuraldsp.com/quad-cortex

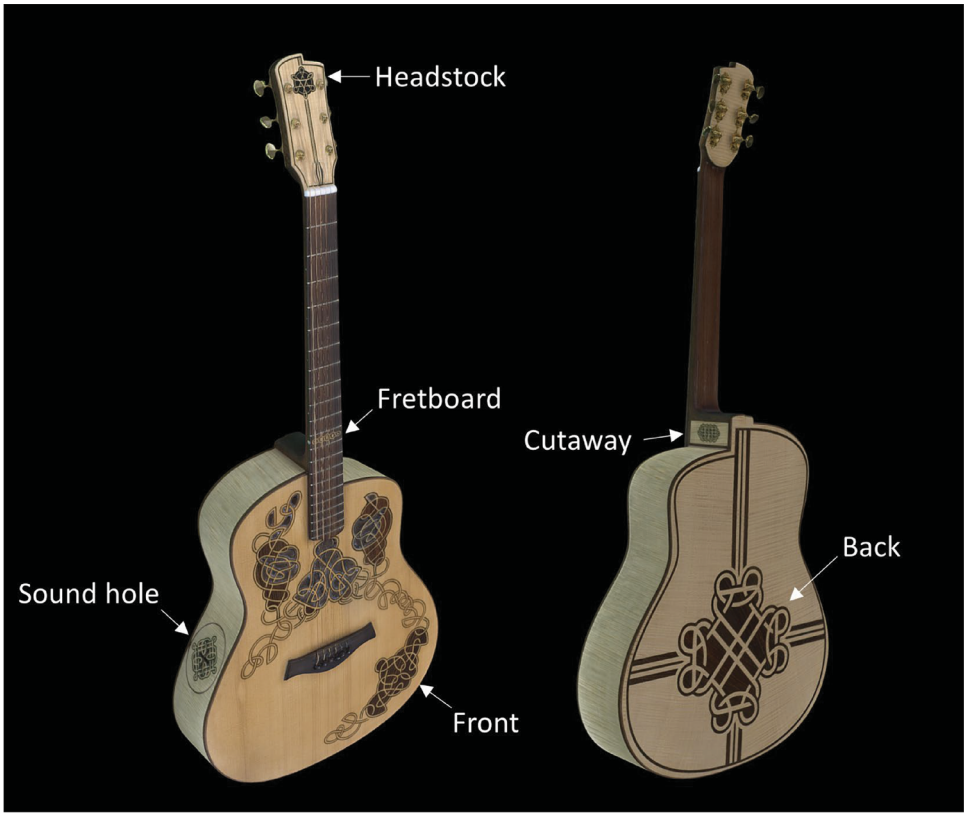

Figure 2. Screenshots from a 3D model of the Carolan guitar constructed using Photogrammetry. The labels point to the six different Artcodes that were inlaid into the body of the guitar. This 3D model was shown to interviewees in our relicing study.

with the aim of better understanding this controversial idea and sensitising us to opportunities for digital support.[7]

We conducted in-depth semi-structured interviews with guitarists to reveal their attitudes and everyday practices in relation to relicing. These were conducted online due to restrictions on meeting and travel that were in place at the time due to the global COVID-19 pandemic. We asked participants about their musical background, experience, and practices, and invited them to show us examples of their instruments and talk us through the stories behind them. The interview included a provocation in which we showed them a 3D model of a guitar (The Carolan guitar, see below and Figure 2) that we had captured using photogrammetry and invited them to consider the proposition: 'if a machine could capture and replicate the physical features of your guitar and that guitar was subsequently destroyed or lost, what features, if any, would you ask the machine to reproduce?'

The structure for guiding the interviews was partially devised following a preliminary exercise in which the research team wrote personal reflections about guitars that they own which included accounts of acquisition, use visible wear, tear, repair, and modifications. The team reviewed these accounts and, importantly, no researcher indicated any experience with, nor any bias in their preference for or against reliced guitars. The accounts also contributed to the creation of a set of generic prompts and questions grouped in four parts: (1) about the participant's musical practices; (2) about their views on guitar relicing; (3) about any instruments of personal interest; and (4) about their digital practices in relation to guitars, and their response to our provocation.

Recruitment targeted various stakeholders in the musical instrument value chain including, but not limited to, relicers (recruited from two Facebook guitar relicing groups), traders, luthiers, and players/owners of genuine and/or reliced guitars. Table 1 shows the demographic of the 11 interviewees who participated. 10 of the participants indicated that they were actively performing in some capacity, 5 of whom identified as professional musicians, in which their main income is derived from their musical practice. Of the remainder, 2 identified as amateur musicians, and 3 as semi-professional earning a secondary income from their musical practices. 5 of the participants (including the 3 instrument builders) were

[7] Ethics approval for research involving human participants was approved by the University of Nottingham School of Computer Science Ethics Committee (ref: CS-2019-R45). Approval process included recruitment materials and methods; research data gathering and storage; and participant information and consent forms.

Table 1. Participant demographic and musical practices.

Participant ID	Gender	Estimated age range	Musical practice
P1	F	50–59	Musician (Acoustic Blues)
P2	M	40–45	Semi Pro Musician Professional Audio Engineering, Education, Hobbyist Instrument builder
P3	F	35–45	Amateur Musician, hobbyist instrument relicer/designer/builder
P4	M	25–35	Guitar Collector and former professional musician, now turned-amateur (not actively performing)
P5	M	40–45	Professional musician and guitar teacher
P6	M	36	Semi-pro musician, plays in several bands
P7	M	40–45	Professional Guitarist: Performance accompanist, recording, and teaching
P8	M	25–30	Professional musician: live performance and teaching
P9	M	30–40	Professional musician: live performance and teaching
P10	M	50–59	Professional musician: live performance and teaching
P11	M	25–35	Performer / Luthier

enthusiasts in the world of relicing and 3 had purchased purposely reliced guitars. 2 of those participants were involved in relicing instruments in an amateur capacity and 1 participant is a professional luthier who does relic guitars, but not exclusively.

The primary concern for gathering these demographic data is not to explicate our findings through any kind of quantitative reasoning, but to ensure a range of stakeholders within the guitar community were represented in the research, and to qualitatively capture a gamut of opinions and experiences. Through our interactions with the guitar community the topic of inquiry, as it is articulated by its members, is made observably reportable to anyone who cares to take note. This in turn elucidates some generalisable insights, not in terms of an exhaustive survey of the problem space, but as recognisable features of the phenomenon under study (Crabtree et al., 2013), for example the practical reasoning for a guitar purchase, or the aesthetic appeal of one guitar over others are all made explicitly familiar to the observer.

A team of four field researchers conducted the online interviews with participants using the Microsoft Teams telepresence platform. Each researcher was required to make notes for every one of the interview's four parts and do semi-automated transcriptions using data generated by Microsoft Teams. The processed research data were then subjected to a thematic analysis, beginning with online data sessions to discuss and familiarise researchers to the participants' responses. The lead field researcher then analysed the data in more detail, filtering and coding the interview data to identify recurring phrases of interest. From these codes a set of themes were generated, defined, and reported back to the research team for review before being written up in a final report with some example extracts.

Relicing and modification

As might be expected, opinions surrounding relicing were divided among the participant group. Those recruited from the DIY relicing community communicated a positive and insightful outlook on the phenomenon that furthers our understanding beyond what the uninitiated observer might expect. Opinions amongst those less familiar with relicing tended toward the most common criticisms that we came across on online forums and articles when initiating our research into this phenomenon.

Considering the case against relicing, for some participants commercially available pre-reliced guitars were viewed as trading in the disingenuous, selling a false narrative to the consumer. For example, although participant P4 noted that reliced guitars in the Fender custom shop 'look great', the fact that it was a recreated look 'feels a bit disingenuous [that] I find that a bit lame, [so] no I wouldn't [buy one]' (P4). The perceived expense of commercially reliced guitars further compounds this issue, as p7 noted, 'why pay extra for someone to scratch your guitar?', but further still it is an affront to the value of natural ageing and hard-earned wear, as they continued, 'I just don't see the point in it, because if you play it enough [it will wear naturally]'. 'Authentic' wear, however, was considered valuable as p1 explained:

> I have had guitars which have been reliced [authentically] by the people that owned [and played] them and it makes it more special. [There's] something about the musicality that that instrument provided, where it's been? […] it's got its own material history hasn't its [the] idea that objects carry stories? (P1).

Turning to the case for relicing, others 'buy in' to the aesthetic as both p8 and p11 observe, 'I just think it's cool. It's getting a little bit closer to owning something like a vintage guitar. It's a classic design and it's as close to owning an original as I'm going to get' (P8), and 'If it's done well and then if it's done tastefully and it looks original, then I think it's I think it's a form of art in itself' (P11). Participant 1 deliberately highlighted their awareness of what they were buying into: 'I don't feel that degree of shame or embarrassment or that I'm being hoodwinked in anyway by a company by buying a relic guitar, I don't feel that at all' (P1).

Our most notable finding was how relicing is an important DIY practice that can involve acquiring deep

knowledge of instruments, applying hard earned skills, creative expression, and trying to create the ideal guitar in various respects. Relicing in general, and especially DIY relicing, was seen as enhancing several facets of guitars if conducted properly as we now discuss.

Playability and tone

DIY relicing appeared to be fundamentally about making a 'playable' instrument rather than just the cosmetic treatment of a guitar. The feel of a guitar when it is being played was consistently considered to be its most important characteristic. In arguing the case for reliced vintage style guitars, P8 observed that 'vintage spec guitars don't play that well, so I'm owning things for aesthetic reasons over functionality' This highlights that modern manufacturing techniques create for more consistent and playable instruments, so the deliberate relicing process adds the desired vintage aesthetic while delivering modern playability. P2 who makes and relics his own guitars discussed this in relation to sanding down the neck of one of his guitars – a common example of relicing practice – 'it's a very worn looking neck but it's still pristine in terms of you how it feels [...] Yeah so hopefully nothing would affect any playability on it at all, because first and foremost it's a playable guitar' (P2).

Deliberately wearing away glossy finishes was believed by some to improve its acoustic resonance:

> The less paint there is on a guitar [...] the more I can feel the guitar resonate when I play it loudly. It's (got) more acoustic properties than a guitar that's got a thick poly (cellulose) finish on it all the way round. (P3)

Revealing how relicing can also be associated with the search for a suitably vintage tone. Achieving a desired playability and tone can also be brought about through other vintage modifications such as replacing electric pickups and wiring to change the sound, or more substantial modifications that require professional services, such as re-fretting or refinishing a guitar.

P10 offers an example of the search for a vintage sound,

> I bought a Les Paul Standard and I didn't like the pickups of a Les Paul standard, so I put in some custom ones, they're called custom-bucker pickups which are much more like the 70s PAF pickups which are in my [Gibson] 335.

Modification and relicing practice can also be about trying to upgrade a cheap guitar to be on par with a more expensive one, as p11 discusses, '[to] see how much difference the relicing process makes to a guitar, but also, I changed the pickups and the electronics [...] to see how good you could get a really cheap, basic guitar to sound' (P11). Modification may go as far as constructing instruments from individually acquired parts, which is a practice unique to Fender style guitars that have a bolt-on design at the join of neck and body (a historic design feature for manufacturing efficiency that subsequently appealed to guitar modifiers), 'Yeah, I normally swap something when I first get them [...] I've changed necks before [...] Yeah, I normally tinker' (P4). When asked about the purpose of this tinkering they noted that, it was, 'probably 60% playability then 40% might be aesthetic'.

Aesthetic

For those in the DIY relicing community relicing is also an aesthetic choice that, as P1 noted, should not be treated differently to any other choice finishes and customisations available on the guitar market, 'I'm OK with buying a reliced instrument is because I see it as a type of finish. And there are so many types of finish out there, you know [...]. P1 goes on to highlight, that for him relicing is about the aesthetics and, 'less about [...] being sucked into that hyperbole of old instruments sounding better and everything'. Many owners veer towards lighter relicing, maybe as this more closely represents natural wear and tear, 'My tastes aren't (toward) heavy reliced (guitars), but I do appreciate them obviously' (P11), and,

> I personally like is seeing subtle signs of wear and tear, so it's very small things like weather checking, finish rubbing through into the wood, subtly done, the metal wear takes on a kind of patina, where it goes but cloudy and a little bit dull. Things like that I get a kick out of. (P8)

Differences across brands

Participants considered the relic aesthetic as only being applicable to specific 'vintage' brands, 'I tend to think relicing looks better on Fenders [...] I don't think Les Pauls [i.e. Gibson] look particularly good reliced' (P6), and 'definitely not Gibson's, you really very rarely see relics' (P11). Participant 11 goes on to speculate that heavily reliced finishes are considered best suited to the Fender brand as their guitars are traditionally seen as, 'working musician's guitar [...]' and conversely observes, 'Gibson owners are quite concerned with aesthetics anyway, but the other the other way [...] very flash and ornate guitars [...] so I think they are already heavily invested in how a guitar looks in that sense, pristine' (P11).

Aesthetics on stage

For gigging musicians, reliced instruments might be appropriate to specific performance contexts, such as when appearing on stage in a theatrical production or playing in a tribute or covers band, as P6 highlights,

> If you're in like a Rolling Stones tribute band, for example, you might have a battered Telecaster custom for that, you know, the Keith Richards side of things which kind of works in that respect, where the looks are just as important [as the sound].

Uninhibited use

A somewhat surprising motivation for relicing was a perceived freedom to use a guitar with risk of damage. P2 noted feeling relieved of the obligation to preserve the condition of the guitar from knocks or scrapes while in use if it is already a 'bit knackered', 'If I bang a Suhr [i.e. high-end brand guitar], that will ruin it forever, but if I bang a [reliced] Strat it almost makes it better' (P9). In short, reliced guitars may have a disinhibiting effect on the player that makes for a less constrained playing experience. However, there is a threshold when relicing shifts from imparting desirable effects on the tone or playability. So, 'when it compromises functionality then it gets replaced or repaired' (P8).

Materials

One subtlety of relicing revealed by our interviews is the importance of working with authentic materials and techniques. Much of the relic aesthetic is owed to legacy manufacture and finishing techniques, for example P11 noted how vintage guitars were traditionally finished with a thin layer of nitrocellulose paint or lacquer that over time displays wear more easily than more modern paints, 'The biggest mistake most people seem to make, is that they try and relic a cheap finish and it has to be nitrocellulose, or acrylic lacquer' (P11). This kind of attention to authentic materials and processes is a fundamental part of DIY relicing and two participants at least used professional services to refinish their guitars using authentic materials.

Personal meaning and patina

Our interviews revealed that DIY relicing could enhance the personal meaning of guitars as musical instruments. However, this was not so much about seeking associations with famous musicians as it was about DIY relicing being a personal journey of learning how to construct, modify, and personalise a guitar; a creative endeavour that those involved ultimately derive pleasure from, regardless of the results and sometimes sharing those results with others. Participants revealed the importance of a guitars' patina to helping establish personal meaning by enabling them to recall stories of incidents in its life. P11 observed,

> It [guitar] was stored in a basement for a long time, so I remember that's what's caused [cracking of the paint finish], it got cold in there that's probably what's taking a big toll on it. But I associate it with that basement […] I like it, yeah, it's got a story.

While p9 commented,

> Oh yeah. The gold Les Paul had a headstock break. I was playing it in the back of a band van right. […] I think somebody closed the door on it […] took the headstock clean off […] And I always wished that I could afford to buy one without the headstock repair because it always annoyed me every time that I looked at it. (P9)

Digital practices

Participants revealed various digital practices in pursuit of relicing. Several described keeping digital records. P11 photographed the relicing process, 'I tend to photograph every stage in some degree […] I like "before and after" pictures' and to support future work they may do on the guitar, 'and I keep photographs of the wiring and stuff in case I forget where things went'. P10 documented the serial numbers of the guitars in their collection as proof of ownership. P3 recorded the electrical parameters of the pickups that they installed so as to help determine the contributing factors of a guitar's sound,

> the Internet offers those opportunities to find out what the difference between like an AlNiCo II magnets and AlNiCo V magnets in a pickup, what does that actually do to the sound and […] finding out about all these things and test running them and experimenting is fun, I love all that stuff [8] (P3).

A key affordance of participants' digital practices is the ease with which information can be stored and retrieved, either as a means of personal documentation or for accessing topical information for research, but further still in the interests of participating, contributing, and interacting with online relicing communities via social media.

The use of social media featured in some of the participant's musical practices, including new acquisitions and items for trade, modifications, relicing skills and techniques, and the progress and results of a guitar building project. Participant P11 contributes to the DIY relicing community, from which they learn and share relicing techniques, i, and 'I've got [techniques] from YouTube videos' (P11). P3 derived inspiration from a Facebook relicing group

[8] https://www.fender.com/articles/tech-talk/what-are-alnico-pickups

> to go and try stuff […] it just embraces anyone who tries to relic a guitar and offers advice and, you know, regardless of how your guitar turns out people are like 'nice one mate, you tried it, go for it, good stuff'.

Recreating a lost guitar?

Finally, we turn to our 'extreme relicing' scenario in which a player's own lost or stolen guitar might be recreated from suitably rich digital record. For most of the participants, recreating the superficial appearance of a guitar was consistently secondary to regaining its feel/playability. For some, they would try and find a replacement with a similar vibe, 'I would search for another one, which could embrace the feeling that I have on this one […] not with the naïve conception of how it will be the same' (P5). P3 noted the replacement would need to feel the same, aesthetic appearance would not be enough,

> if it was possible to do it perfectly 100%, I would, but if it ended up being guitar that look the same but didn't have the same feel and playability […] I wouldn't want it. I would need to be 100% sure that it would be the same guitar. (P3)

For others the emotional connection to a lost instrument would dissipate over time,

> If the guitar got stolen or lost in a fire or something [and] I was offered a new guitar that replaced it immediately afterwards, when I was still emotionally upset, I would probably go for exact replica. If it was like a year later when that emotional thing had died back a bit, I probably would go for a regular guitar. (P10)

Participants commented that each guitar is unique due to the woods used in construction; slight manufacturing inconsistencies between batches of electronics and hardware; and material ageing and how well an instrument has been 'played-in'. Overall, participants general felt that these factors were not only impossible to truly replicate, but also the most insurmountably important factors over and above any superficial replication of the instrument. Others cited the emotional attachment to their instruments as irreparable, even if their guitar could be replicated perfectly, it would still 'not be the same'. Ultimately, most participants opted to eschew a hypothetical recreation of their own most valued instruments in favour of starting again with a new guitar. Even when committed to the idea of relicing at a deep level (i.e. trying to recreate aspects of tone and playability), interviewees felt that the identities of their own guitars could not directly be transferred between instruments. In short, the journey of relicing appears to be more important than the product.

In summary, while relicing does appear to be a somewhat controversial practice, it is also a rich one for those who do engage with it. Relicing appears to be about far more than simply buying into a fake story. It encompasses a search for playability and tone and an appropriate performance aesthetic. Moreover, there appear to be relicing communities who enjoy the skilled DIY practice of crafting and modding reliced guitars. Digital technologies already play a role in these practices through documentation and social media. Finally, while the patina of instruments does appear to be important for associating personal stories with instruments, participants were sceptical about wanting to recreate relics of their own guitars should they ever be lost or stolen.

Case study two: probing the digital identities of guitars through the Carolan guitar

If our first study was concerned with understanding the current and predominantly physical practices surrounding guitar identities, then our second, in contrast, set out to explore possible future digital practices.

The Carolan guitar was created as a research probe that employed digital technologies to capture its lifelong digital footprint and so gradually establish a unique identity for an individual instrument. The project is an example of research through design method, a practice-led approach in which research knowledge emerges from reflection on design practice (Zimmerman & Forlizzi, 2014; Gaver, 2012), in this case the practice of first making and then living with and sharing a musical instrument that documents its life story in the form of an extensive blog. It can also be viewed as an example of a technology probe (Hutchinson et al., 2003), a high-fidelity prototype released into the wild to gather insights from users in context. It also incorporated elements of auto-ethnography in which the guitar became a device for the lead researcher to reflect on their own practice. It is important to acknowledge that the findings from this kind of design-led and somewhat auto-ethnographic approach are necessarily subjective (Neustaedter & Sengers, 2012) – reflecting the goals, experience and context of the research team – rather than making claims to objectivity or reproducibility. Nonetheless, or perhaps even because of this, they are illuminating with respect to revealing the storytelling potential of augmented instruments.

The guitar is named Carolan in tribute to the legendary Irish bard and harper Turlough O'Carolan who roamed Ireland at the turn of the eighteenth Century, composing and performing tunes and stories, and who is considered by many to be Ireland's national composer. This aspect of the guitar's identity is most obviously visible in the decorative design of the intricate Celtic knotwork that is inlaid into various surfaces. Importantly,

these inlays are also interactive; employing a technology called Artcodes that enables scannable visual markers to be embedded into hand-made designs (Benford et al., 2017). Scanning six distinct areas of Carolan's decorative inlay with a phone, tablet or other camera-enabled device will retrieve six different stories from its blog. This digital affordance enables Carolan to wear its adornments as both a unique physical identifier and as a proxy for its digital identity, which is openly accessible online. This openness is also key to its role as a research probe and is an additional affordance of documenting our research digitally.

It is worth noting that as a bespoke instrument, made and maintained by independent luthiers, Carolan's documentation is not necessarily assured, nor its identity fully conceived before it is released to the world. In contrast, and as discussed above, mass produced instruments are often marketed with designer identities; traded with certificates of provenance; and even afforded manufacturer warrantied aftercare, registered ownership, and condition and maintenance documentation that can conceivably exist in digital form and are often linked to a unique physical identifier such as a serial number. Carolan is remarkable in this respect, as its unique inlay designs are an overt intermediary to a still evolving 'digital identity' – which in Carolan's case is a set of rich ethnographic accounts that not only incorporates the concerns above, but also includes many other aspects of its life story and its role as an open research probe.

At the time of writing, Carolan is ten years into its journey and remains active. A detailed account of Carolan's life can be found in an online blog (carolanguitar.com) which we reference below using braces (the notation X refers the reader to blog post X). It therefore also provides an example of longitudinal research (Karapanos et al., 2021) and auto-biographical research (Neustaedter & Sengers, 2012). Previous publications, relatively early in its life, covered the Carolan's design (Benford et al., 2015) and reflections the first three years its life (Benford et al., 2016). The following account draws on these early papers but also many subsequent episodes in Carolan's life to present a series of vignettes that illustrate diverse ways in which digital technologies can support an instrument's unique identity.

Design and build

The design and build of Carolan were richly documented through 25 blogposts over the course of nine months covering its concept, creation of its interactive Artcodes, and build. This rich documentation included photos of the original whiteboard and notebook pages where the concept was first worked out and the Artcodes first sketched 4,5,9; evidence of the choice of tone woods, most notably some mahogany reclaimed from an old wardrobe of the guitar's neck and inlay 10; photographs from the luthier's workshop documenting the build, including two videos taken from inside a CNC laser etcher of the soundboard 17 and back 14 being etched with the Artcode designs; a video of the luthier playing its first ever song at the moment of its birth 23; and an official photoshoot that captured high quality image of the completed instrument 26.

An early decision concerned where on the instrument to locate the interactive Artcode designs. Ultimately, we chose to inlay six distinct visual codes into separate locations on the guitar – headstock, soundboard, back, top, cutaway and fretboard, each of which was intended to offer a different degree of visibility and access (Figure 2). The front and back are reality visible at some distance, potentially even to audience members; the headstock, sound hole and cutaway are accessible to someone who is very closeup to the instrument (e.g. holding it); while the fretboard code fretboard code can only be scanned by someone who first removes the strings while maintaining the guitar 9.

Maintenance

Carolan's digital practices extended to documenting ongoing maintenance. This included several major repairs and set-ups, most notably documentation of a neck reset and installation of a new pickup 66 and repair of a crack on the soundboard and bridge replacement 93. There was also an active attempt to document the guitar's patina resulting from natural wear and tear including a photographic cataloguing of various dinks and dents and capture of the stories of how these came to be 75. This was subsequently extended by using photogrammetry to scan Carolan and construct a 3D model, annotated with notes of key build features and patina 77 (the model shown to participants in the first case study reported above).

Travelling

Once built, Carolan was released into the world to begin life as a travelling guitar, capturing new stories as it visited diverse locations and passed through the hands of different guitarists (over fifty to date). There was no prescribed method or system for passing Carolan from player to player; rather an informal arrangement emerged in response to various opportunities that arose. Two kinds of opportunity arose from contacting professional musicians, especially ones who were 'in town' to perform, and from the offer from a local folk club to host Carolan as a 'guitar in residence' as we now discuss.

We took the opportunity for Carolan to meet Professional guitarists as they toured through nearby venues or to visit them for interviews who recorded tunes and songs and gave us insights into professional attitudes to guitar ownership. Kevin Armstrong, guitarist with David Bowie and Iggy Pop among others, explained some of the challenges he had encountered trying to recreate his own sounds from past albums when going on tour (it is interesting to note that the players who first innovated particular sounds face this problem, as well as musicians who may subsequently try to cover their material), suggesting that the details of particular setups might be documented as part of an instrument's history 39.

Carolan also encountered many everyday players, by visiting various clubs and sessions, taking up a temporary residency in a guitar shop 33,36 and becoming the resident guitar at a local folk cub where it spent weeks at a time in musicians' homes 81, 82, 87, 88, 90, 95, 101, 109. These players extended Carolan's digital record and blog with recordings of favourite songs and tunes from their personal repertoires as well as personal memories of guitars, learning to play, influences and local music scenes, creating a small corpus of 'oral history' materials about local folk music practices.

We also experimented with using movement and temperature sensors along with a self-activated stills-camera mounted inside the instrument to capture the stresses and strains in experienced while undertaking an international road trip from home in the UK to Louisiana in the USA 46.

A key practice that emerged during these visits involved reconfiguring the mappings between Carolan's six Artcodes and the digital resources they pointed at for each player it encountered. The aim was to set up a personally meaningful experience to introduce the guitar to each new custodian (e.g. connecting to recordings from its archives they might find inspiring) and even leaving behind a final mapping that connected to the new material that they themselves had added. We also realised that new mappings might be required for each new activity that the guitar participated in, for example when visiting a particular folk club or jam session.

A further idea that emerged from this travelling was that Carolan should leave behind some physical memento of its presence to serve as a tangible reminder of its visit and that, like the guitar itself. this should be decorated with a scannable Artcode. We created various mementoes decorated with Carolan's Celtic knotwork including picks, badges, and stickers 44 and helped one player to attach knotwork to an old acoustic guitar that they were restoring as part of a guitar modding project 69.

Recording

Carolan took part in various recording sessions including in home studios 38, as part of bands making videos for fans during the time of COVID-19 restrictions on live performance 85, in a recital hall 41 and in professional studios. One extended recording project documented the guitar's involvement in initial writing sessions to compose new material 43 which eventually led to a recording session at Real World studios 57 followed by the reproduction of Carolan's Celtic knotwork on an interactive album cover and the instrument's appearance at the album launch gig 58.

Much of the day-to-day capture of songs and tunes involved video recording and much of this was manually captured by players themselves. We also experimented with mounting cameras on and inside the guitar to provide close-up perspectives for video recording's including a guitar's-eye view of the world 68, 94 and with movement and voice activated cameras to more easily or even semi-automatically capture materials.

Documentation of the lessons learned from these various recording activities was captured and compiled into the guitar's evolving user guide. Whereas conventional guitar user guides tend to the minimal at best, Carolan's is rich with detailed guidance about how to best capture its voice in the studio (recommended combinations of mics, positions, and settings and effects in digital audio workstations) or record video on the road (tips as to useful accessories and best practice for using these).

Performing

Carolan's participation in live performance ranged from informal Irish music sessions and folk clubs 25, 40, 79, appearing with bands and solo acts at formal gigs 70, 97. It appeared as a regular guitar in many of these, though its unusual appearance often attracted interest from audiences, leading to opportunities to introduce it to new people and explain its history. However, some performances involved overt references to its life story and even use of its interactive capabilities to conjure this up on stage. Professional folk musician Tim Edey brought Carolan on stage with him during a local performance, explaining its backstory before performing a tune 35. A pre-recorded performance at an online music festival during COVID-19 lockdown demonstrated the idea of scanning Carolan to retrieve and then play along with backing tracks 78. This inspired the development of a bespoke Carolan show, first delivered at the local folk club that hosted its residency, that combined playing Carolan, explaining its concept and history, and scanning it live on stage to trigger specially prepared videos documenting

its making, explaining Artcodes, summarising the residency programme, and a backing track featuring other local musicians to be played along to live 102.

The technical setup for this gig involved mounting a mobile phone on a stand and connecting this to a short-throw projector and PA system so that Carolan could be scanned by pointing it at a fixed camera rather than pointing the camera at the guitar as had previously been the case. One key lesson from the performance was that some codes were more naturally performative to scan than others, due to a combination of the gestures involved and the reliability of the codes. The codes on the front, back and top sound hole proved reliable, even at some distance from the camera, while turning the guitar over in the hands to switch between them, while an unusual gesture, could be performed quite comfortably and naturally, at least when seated (this would have felt quite different when standing and using a strap to hold to guitar to the body). In contrast, the codes on the headstock and in the cutaway were trickier to trigger while showing them to the camera required less comfortable lateral movements of the instrument.

Research

Finally, we note that Carolan's life story as recorded on its blog also featured many stories from its life as a research probe. These began with summaries of key papers about the project and accounts of travelling to conferences to present these 46, 53, 56, followed by commentaries on other guitar and digital music research projects 61, 65, 67, 83, and then eventually a series of musings on wider issues often connected to other disciplinary perspectives 91, 96, 98.

Discussion

In this discussion we begin with some general observations surrounding the current understandings of non-digital and digital instrument identities, the relationship of those to our studies, and the prospect of consolidating those in Product Service Systems (PSS); next we discuss specific considerations for PSS surrounding forging, performing, and sharing instrument identities; and finally, the broader considerations for future work surrounding such a system are summarised.

Reframing instrument identities – non-digital identities, digital identities, and product service systems

To contextualise our findings, we first discuss existing understandings of guitar identities.

In non-digital terms, the guitar is ubiquitous due to its historical role in cultural exchanges across colonial territories, and to its disruptive influence in extending the sonic possibilities of the modern musical canon (Carfoot, 2006). This ubiquity underpins the guitar's status as a 'democratic instrument' that is integral to personal and cultural identities, in which picking the right guitar for 'the scene' is as important as picking the right garments (Everett, 2003). The 'right guitar' identity is displays in its physical form through its make, model, shape, hardware, electronics, finish, materials such as individual tone woods, visible patina, and other 'indexical' elements such as signatures that reinforce connections to famous players (Fernandez & Lastovicka, 2011).

In digital terms, instrument identity extends to the algorithms and data that enable the primary function of sound making, from purely digital instruments, to embedded digital technologies such as tuners and effects into conventional guitars. This is particularly true of the amplifiers, pedals and accessories that form part of the guitar's wider ecology, and which employ digital modelling and related technologies that can be routinely upgraded, for example Fender Tone Master amplifiers (Breathnach, 2023).

Our case studies have added to these understandings in unique ways that leverage digital practices in the process: the curious case of guitar relicing both encompasses and disrupts guitar culture and identity; and the Carolan guitar is central to an unprecedented richness of ethnographic accounts that make up its identity. We argue that the growing importance of the digital aspects of identity call for a fundamental reframing of how the industry conceives of guitars as products.

Taking a lead from other sectors, manufacturers are providing new kinds of product-service systems (PSS) that bundle physical goods with digital services (Smith et al., 2014). Cars are delivered through service-like leasing agreements, while aircraft engines are leased to deliver 'power by the hour' (Smith, 2013). We propose that future musical instruments might also be considered a PSS that bundles digital sound making services as well as identity services that maintain their digital footprints over their lifetimes. In the following sections we reflect on our two case studies and the wider literature to consider how augmenting the identities of musical instruments can enhance the experience of playing and owning them, and the various ways in which this might be achieved in a PSS.

Forging instrument identities

We begin by, discussing how instrument identities are forged through a combination of physical and digital practices. We identify four general benefits:

Utility

Our relics study reveals how an appropriate identity enables instruments to better fit both the visual and sonic aesthetics of a particular musical genre. This extends beyond matters of personal taste, for example by meeting the needs of everyday musicians who play in covers and tribute bands. Storing data about specific setups might help musicians recall and recreate sounds, from exploring the sonic possibilities of an instrument through 'tinkering' as noted in previous research (Pinch & Reinecke, 2009) to professionals trying to recreate a particular show many years later as reported in the Carolan guitar case study.

Provenance

Provenance concerns surrounding the guitar trade include authentication of new limited-edition instruments; second-hand, vintage, and collectible instruments of multifarious origins; compliance with endangered species legislation during import and export (Furlett, 2015; Greenberg, 2016); and informing the identification of stolen instruments. The Carolan guitar reveals how digital augmentation can greatly enrich provenance through detailed records of making (bespoke luthiers often provide such documentation); evolving patina, which may help identify an individual instrument; records of maintenance and repair; and histories of its players, performances, and recordings.

Meaning

The literature has explored the complexity of human-artefact relationships and the personal and cultural value that everyday objects can embody. Musical instruments are particularly disposed to developing identities through its association with an individual's memories, legendary musical figures. This is reflected in the participants' enjoyment of relicing guitars with a visual and sonic aesthetic that meaningfully echoes their personal sensitivities and experiences. Meanwhile, Carolan shows how digital augmentation can be leveraged to capture and retrieve vivid accounts of personally meaningful memories in contribution to its identity's natural development, that can be immutably coupled to the physical instrument and enhance its value as a cultural artefact.

Making

Our case studies reveal how building an instrument's identity may involve various maker practices which are valued by DIY musicians. Imbuing a guitar with an identity through relicing can evidently be a skilled and expressive craft practice; processes of tinkering, modding and self-building may be documented as part of maintaining and sharing a record of craft practice; and the act of blogging with Carolan became valued as a digital craft practice.

Our relicing study revealed a tension concerning the authenticity of the identities that are bestowed on musical instruments. The practice of relicing was controversial, being viewed by some as disingenuous and fake, and by others as an artistic and creative DIY practice, like those of modding and self-building, reflecting a wider interest in making and maker communities among musicians (Morreale et al., 2017). We propose that the practices of sharing photos, videos and even blogging as employed with the Carolan guitar are similarly creative activities that might be enjoyed by the owners and players of instruments as part of forging their digital identities.

An underlying tension here concerns who is bestowing an identity on an instrument and when. Traditionally, manufacturers have attempted to do this through branding, signature editions, replicas, and now relicing, typically applied at the start of an instrument's life. Alternatively, we have revealed how owners can also imbue their instruments with distinct identities throughout their lifetimes, through tinkering, modding, DIY relicing, and now potentially through recording and sharing data too. We propose that the tension of authentic identity may be resolved by combining the two approaches in which both manufacturers and owners employ physical and digital techniques to co-create and shape an instrument's identity over its lifetime. In much the same way that social media can be viewed as being co-created by providers and users, so we argue, can future musical instruments.

Performing instrument identities

To maximise the experiential value of a musical instrument, digital identities need to be available for a diversity of musical activities such as learning, practicing, performing, and even maintenance and repair. In terms of the instrument's digital footprint, this can be manifested while in use to both to capture identity 'data' when the instrument is to hand, for example recording music or documenting repairs; and to recall such data when talking about the instrument or even performing with it. The latter is illustrated in a live event with Carolan (see carolanguitar.com 35) that mixed real-time performances with recalling stories and playing along to recordings from its archive (an emerging performance trend amongst heritage acts that perform with videos of past members). Our experience of delivering performances with Carolan revealed that invoking and interacting with an instrument's digital footprint can be a performative act albeit one that is challenging in terms of simultaneously handling the instrument, as identified in studies of guitarists' learning practices using digital

media (Avila et al., 2019). This opens the possibility that such interactions might enhance performances, for example, interactions with Carolan rely on showing the guitar to a fixed camera and scanning codes in a suitably performative way while holding it, an observation that reflects Avila et al.'s (2020) account of 'encumbered interaction' when trying to access digital media when holding guitars.

Such possibilities require that the physical and digital facets of identity be technically connected in some way. Carolan demonstrates one method of achieving this through the Artcodes visual marker technology, however other possibilities include embedded identity tags (RFID and Bluetooth beacons), or sensors (e.g. accelerometers and gyros) to recognise specific patterns of movement such as being taken off a stand or performative gestures, to musical codes in which sequences of musical notes trigger interactions (Greenhalgh et al., 2017). Expending this concept further, Carolan also revealed opportunities for capture through the placement of automated cameras or movement and heat sensors inside the instrument to deliver data that could support sharing of interesting stories about it, reflecting the notion of the 'quantified self', albeit for instruments.

Whatever approach is adopted, our experience with configuring Carolan's six distinct Artcodes highlights the requirement for contextual remapping, in which different elements of the instrument's digital footprint can be invoked under different circumstances, such as those already discussed. Co-creating identities therefore requires both manufacturers and owners to be able to configure such mappings as part of the instrument's identity service.

While we argue that the physical and digital facets of an instrument's identity should be connected to enable 'performance', they should not necessarily be dependent. There were clearly musicians who appreciated playing Carolan without accessing its blog and conversely, researchers and others who accessed its papers and blog without needing to play the guitar. Similarly, our relicing study revealed diverse attitudes to both physical (e.g. relicing) and digital (e.g. data recording) identity practices suggesting that we need to support those who wish to engage with one or both rather than insisting they are always connected.

Sharing identities

So far, we have discussed identity in terms of one-to-one relationships between instruments and musicians. We now broaden our focus to consider sharing identities for which we offer two perspectives.

Brand and instance level instrument identities

Firstly, we envisage augmenting and sharing instrument identities in PSS that combine brand and instance level services – physical and digital, customised, and personalised. At the brand level, identities are established through distinctive combinations of make, model, style, reissues, signature models, that might be enhanced through digital documentation, and even celebrity backstories (of the kind often published in popular guitar press to accompany new product announcements). Although a custom-made instrument, Carolan's approach to digital identity is distinct from this choice-based approach of customisation, operating in a reverse direction that gradually adds to an instrument's identity to elevate it from mass obscurity to a notable individual. This is in an example of personalisation, in which digital data are leveraged to tailor services to a specific individual (Sundar & Marathe, 2010). At the instance level, unique identities are forged through limited editions, optional fittings and finishes, custom hand-made builds, and in parallel, identity services will also support instance-level practices including the capture and performance of personal stories, physical modding, and DIY relicing,

Leveraging these data, instruments can then be connected. Individual instance stories, might be shared with other instances across the brand, as might stories from celebrity endorsees. In other words, all of those associated with the brand, from famous to everyday players, might share stories through their connected instruments. The result would be an instrument that becomes connected into its own social network of other instruments, all of which share their unfolding histories and support online forums for discussion to create a shared identity. Such a service requires digital data to flow in two directions: from manufacturers to consumers in the form of provenance, product information and celebrity stories, but also from consumers to manufacturers and other consumers, in the form of sharing information about modifications, wear and tear, patina and of course the personal stories of everyday players. Drawing on the experience of social media and other digitally native products such data might be of more generally useful to manufacturers, if gathered ethically (e.g. with appropriate consent and reward). For example, collecting and analysing examples of real patina from many consumers might inform the relicing practices of custom shops.

Ownership and transition of instrument identities

Secondly, a more temporal perspective on instrument identities that raises further possibilities and questions concerns transitions of custodianship, which we view from two sides:

The incoming custodian. What aspects of the instrument – digital and physical – does the new owner or borrower acquire on taking ownership? Do they have access to its entire digital history or are some parts hidden? Accessing provenance and utility information seem straightforward propositions here, but personal memories less so as previous custodians may not be comfortable sharing these. And what responsibilities do new custodians take on for maintaining the identify moving forward? As a new owner, do I have a duty of care to maintain a venerable instrument, both physically and digitally?

The outgoing custodian. What aspects of identity do they retain access to or even control over (e.g. personal memories) once the instrument has left them? An intriguing possibility is whether they can stay connected to it as it continued its journey; might people like to stay updated about instruments they have sold or passed on? For example, Carolan's various accessories (plectrums, badges, and stickers) are more than a reminder of the guitar's presence, and are scannable access point to its blog; might individual instances of guitar leave behind memorabilia when they move on?

Consequently, any prospective PSS should be designed to support transitions of ownership as instruments move through the hands of different custodians. Building on our practice of reconfiguring Carolan to point to personalised information when we lent it out, there is an opportunity for manufacturers and/or retailers to support managing the digital footprint of current and past custodians and produce memorabilia as part of the bundle of digital services that come with an instrument.

Considerations for implementation

Of course, with any concept that involves the exchange and stewardship of digital data, there are associated practical challenges that include, but are not limited to, privacy, consent, security, longevity, archiving and trust. These issues are exacerbated as we explore the prospects of binding physical objects to a range of digital applications across public, commercial, and private domains. Developments surrounding blockchain distributed data ledger could point toward possible solutions, as a broadening range of real-world practical applications for this technology emerges, such as securing the integrity of transactions in the supply chain (Uddin et al., 2023). Of relevance to our research is the crypto anchors concept (Balagurusamy et al., 2019) for verifying and tracking physical items using the blockchain through three layers: the Physical Object Layer which could be an embedded RFID tag, or unique physical identifier such as Carolan's decorations; an Intermediary Layer for scanning or reading the Physical Object Layer, in Carolan's case the Artcodes application; and the Blockchain Layer for accounting and provenance tracking of items (a proxy for which, we demonstrate in Carolan's blog). Blockchain is also capable of consolidating data blocks as instruments change hands between commercial, private, and public domains and back again, with the use of hybrid public-private domain ledgers. Accompanying these possibilities, however, are a host of further challenges such as the need for industry standardisation, interoperability, ecological impact, and ethical issues, as well as specific issues such as which data those in the guitar community might choose to share or to keep private. Addressing these challenges, however, are outside the scope of this paper and should inform the future work and we hope that in presenting the findings of our research to date we have not only added to knowledge surrounding musical instrument identities but also sensitised designers to the value prospects of product service systems in this domain.

Conclusion

Unlike much previous research into augmenting instruments that has focused extending their immediate capabilities for musical expression, we set out to explore an alternative idea – the digital augmentation of their identities. This involved reflecting on two case studies, one that focuses on the current industry practice of relicing guitars that reveals attempts to imbue instruments with identities when they are made, and a second that probed how a guitar can capture and invoke a history that accrues over its lifetime once it has been released into the world.

Our two case studies reveal diverse ways in which digital identities can enhance our experience of musical instruments, spanning enhanced utility, provenance, and personal meaning, while also further expanding opportunities for DIY 'making' practice and research. We argue that instrument identities should be co-created by both manufacturers and owners and that they can be manifested both physically and digitally. Under this view, an instrument becomes a product-service system, a bundle of a physical product and associated identity services.

Connecting the physical and digital aspects of an instrument through an appropriately flexible (and remappable) embedded technology allows digital identities to be performed during practice, with the instrument in hand, whether inspecting it in a shop, learning and practising at home, or performing on stage.

We have proposed that instrument identities can be augmented at both the brand and individual instance

level to support a combination of customisation and personalisation, and the sharing of stories between multiple owners to create social brands that foster community and shared experience.

In conclusion we invite others to also consider augmenting the identities of instruments as an important, if somewhat neglected, aspect of research into music technology. This might include exploring applications of digital identity services, a wider range of technologies for connecting digital identities to physical instruments and considering instruments beyond guitars.

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