Augmenting a Guitar with its Digital Footprint

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ABSTRACT
We explore how to digitally augment musical instruments by connecting them to their social histories. We describe the use of Internet of Things technologies to connect an acoustic guitar to its digital footprint – a record of how it was designed, built and played. We introduce the approach of crafting interactive decorative inlay into the body of an instrument that can then be scanned using mobile devices to reveal its digital footprint. We describe the design and construction of an augmented acoustic guitar called Carolan alongside activities to build its digital footprint through documented encounters with twenty-seven players in a variety of settings. We reveal the design challenge of mapping the different surfaces of the instrument to various facets of its footprint so as to afford appropriate experiences to players, audiences and technicians. We articulate an agenda for further research on the topic of connecting instruments to their social histories, including capturing and performing digital footprints and creating personalized and legacy experiences.

Author Keywords
Design; guitar; interaction; sociality; internet of things; interfaces; human computer interaction; instruments

ACM Classification
H.5.5 [Information Interfaces and Presentation] Sound and Music Computing.
H.5.1 [Information Interfaces and Presentation] Multimedia Information Systems

1. INTRODUCTION
In 2006 Gaye *et al.* – whilst highlighting how the development of new mobile technologies was in turn forming new opportunities for NIME – outlined the community's core themes as *"interaction, interfaces and music"* [1]. Digital technologies have continued to develop and the Internet of Things (IoT) stands as the latest digital *zeitgeist* that promises to change our everyday lives. An important aspect of the IoT vision concerns instrumenting everyday things to gather rich 'digital footprints' over a lifetime of use. These digital footprints may lend value to things by documenting provenance [2], enabling the telling of stories [3, 4], supporting memory [5], meaning [6, 7] and potentially even transforming them from being smart to being social [8].

The NIME community has a long history of digitally augmenting instruments. Research dating back many years has explored how digital augmentation might extend the playing of traditional instruments such as violins [9, 10] or affect an instrument's sound production and construction [11], while the emergence of 3D printers and laser cutters has fuelled the creation of bespoke instruments [12]. Little has been written however, about how digital technologies might augment the wider social life of instruments: where they travel, who they encounter, the music they play and the audiences that engage with them? And yet for many the social history of a musical instrument is saturated with meaning and value that is continuously accreted over its lifetime. Celebrity instruments, for instance, may sell for great sums on the basis of their provenance while everyday musicians regularly collect and recount stories about their instruments that imbue them with personal value beyond their primary function as producers of sound. As Carfoot writes, "*the sociocultural ideologies that are inscribed in musical instruments cannot be divorced from those instruments*" [13].

In response, we present an initial and ongoing exploration of using IoT technologies to digitally augment a musical instrument – an acoustic guitar – so that it becomes linked to its social history. By interacting with our guitar using their mobile devices, people can explore its digital footprint, discover how it was made, where it has been, whom it has encountered and hear the music it has played.

Our methodology is one of 'research through design' [14] in which we explore this challenge through the hands-on practice of designing and building the guitar and augmenting it with a digital footprint. There are two notable features of our approach – choosing to work with an acoustic guitar and employing a particular augmentation technique that involves crafting interactive decorative inlay.

We chose to work with an acoustic guitar because of its wide appeal and accessibility; acoustic guitars are popular, democratic instruments that are owned by many millions of people. They are also portable, being easily passed from person to person and used in a variety of situations. There is already great interest in the histories of acoustic guitars, such as 'celebrity' guitars that acquire folkloric values to detailed discussions of tonewoods, hardware, construction, provenance and increasingly sustainability. There is little wonder that this has given rise to what Carfoot [13], called guitar diasporas; the varied and many cultures relating to and revolving around the guitar. Indeed, Magnusson and Mendieta [15] reported how players formed…"*an "emotional" affection towards their acoustic instrument and they bonded with its character.*"

There are several technical possibilities for digitally augmenting an acoustic guitar with a digital footprint. We might, for example, embed sensors inside the instrument to capture information about its use and context and communicate this with nearby displays. However, we have chosen an alternative approach in which we embed interactivity into an instrument's surface decoration, enabling people to scan its decorative inlaid patterns in order to access digital information. This utilizes a particular IoT technology called *Artcodes* that enables people, especially graphic designers, to hand-draw interactive patterns [16]. Artcodes encode digital information into the topology of a pattern [17], affording flexibility and playfulness in design. We adopt this approach to explore how various 'touchpoints' for accessing a digital footprint can be made publicly visible to players, audiences and technicians and to explore how digital augmentation can be integrated with the craft practice of luthiery.

This paper focuses on our experience of designing and building our guitar, a process that reveal wider issues concerning how instruments can be associated with digital footprints. Our aim is to show how this can be possible while also framing an agenda for our own – and we hope others' – future research into socially augmented instruments. We now describe what transpired when we brought together a traditional luthier, a graphic designer and software researchers to create a bespoke handmade acoustic guitar called Carolan that could tell its own life story through its inlaid decoration.

NIME'15, May 31-June 3, 2015, Louisiana State University, Baton Rouge, LA.

2. BUILDING THE CAROLAN GUITAR

We engaged a luthier and a graphic designer to collaboratively design and build an acoustic guitar over a period of five months. We adopted a Celtic theme in honour of Turlough O'Carolan, the last of the great blind Irish harpists and an itinerate musician who roamed Ireland around the turn of the 18th century collecting and re-telling stories and music. This theme inspired us to name our guitar 'Carolan' and our graphic designer to create a series of Celtic knotwork Artcodes.

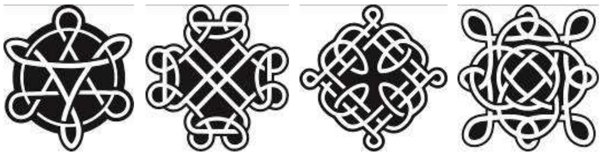

Figure 1: Celtic knotwork interactive Artcodes

We determined to liberally decorate Carolan with patterns (Figure 2) so as to probe diverse modes of interaction. We identified the following target locations: the headstock where the maker's logo traditionally appears; the soundboard as the public-facing front of the guitar; the back which affords a large surface for placing a pattern that might be scanned from some distance away; the top side that is visible to those playing the guitar; the fret board where fret markers are traditionally inlaid; and a 'secret' code in a nook underneath a cutaway.

Figure 2: The finished Carolan guitar

We decided that the Artcodes should be permanently inlaid into the guitar's wood using traditional techniques rather than painted or transferred. Our choice of woods was governed by the presence of Artcodes as well as tonal considerations. Specifically, the need to maximise the reliability of recognition led us to choose lighter woods (spruce for the soundboard and flamed maple for the back and sides) that were inlayed with darker Mahogany to form strongly contrasting patterns.

As the design evolved, so the presence and possibilities of interactive Artcodes began to push back on the form of the guitar in unusual ways. We experimented with more complex Celtic knotwork on the front of the guitar, creating a design that flowed around the body and under the strings and that also comprised a mixture of inlay and strategically placed small sound holes. We realized that the area of this pattern running under the strings could only be scanned when the strings themselves were removed. Therefore, we decided to embed a different code within this part of the pattern so that only people who change the strings – a special relationship to the instrument – would be able to scan this particular code.

The replacement of the traditional sound-hole with clusters of smaller holes triggered a further innovation. In order to provide access to the inside for maintenance (ranging from the routine task of changing the battery for the pick-up to more advanced repairs) we made the sound-hole on the top-side removable, being held in place by a series of small magnets (Figure 3).

Figure 3: The removable and scannable sound-hole

We had initially considered a range of traditional methods such as marquetry and hand engraved inlay. However, the extensive use of inlay in the final design made it infeasible to work with purely manual techniques. We therefore employed a laser cutter to both engrave the patterns into the guitar's tone woods and also to cut out the inlay which our luthier then joined and finished by hand. The complex design of the soundboard proved especially demanding. Indeed, it is unusual to place such extensive inlay onto this structurally important and sensitive surface. The soundboard is under great tension from the strings and thus needs to be strong and stable, but it is also the main resonant surface that produces the guitar's sound. To support the soundboard a number of bracings are traditionally fixed in specific places on its underside and their size, shape and positioning directly influences how the soundboard resonates, contributing greatly to the tonal quality of a guitar. These factors required extended dialogue between the luthier and graphic designer to resolve the exact shape and placement of the soundboard pattern. Figure 4 shows the resulting design. The red areas show the locations of the cut-through soundholes, carefully positioned to give the correct overall surface area to release the guitar's voice, avoid the most structurally sensitive areas of the surface as well as the underlying bracing, while also forming scannable Artcodes.

The result of this extensive design and crafting process was a unique handmade acoustic guitar with six distinct scannable codes inlaid into its different surfaces.

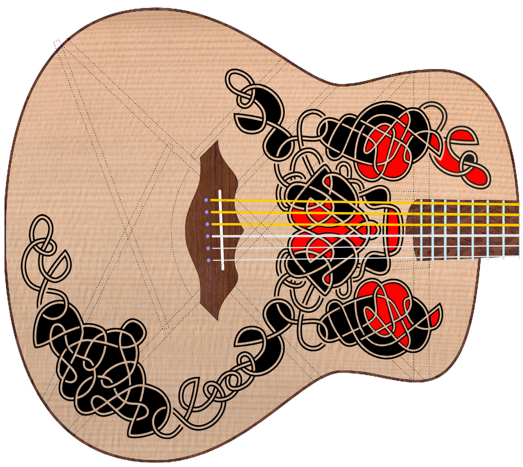

Figure 4: Design of soundboard showing locations of bracings and sound-hole areas.

3. CAPTURING THE FOOTPRINT

Building the guitar was only half the story; the next challenge was to establish its digital footprint. We therefore pursued various opportunities to use Carolan as a probe to engage musicians, documenting their performances, stories and personal reflections. Over a four month period Carolan encountered renowned professional players as they toured through local venues, one of whom performed with it on stage; took up residency in a music shop during a festival where it met local musicians; took part in three traditional music jam sessions; was used to give a small performance; was recorded in home and recital studio settings; and was exhibited and presented at two research events.

Carolan's evolving digital footprint took the form of a blog that featured technical documentation alongside blog posts (including video recordings of performances and interviews) that described its initial encounters with various players. Over the course of the six months we encountered 27 players, 5 of whom were professional, captured 34 tunes and songs and 12 interviews. We published 41 blog posts in total, 26 of which documented the construction stage of the project. As a result of these activities, Carolan's digital footprint quickly grew to encompass a wide variety of information, even in the early stages of its lifetime. The blog remains live and is available at www.carolanguitar.com. The following summarises the composition of Carolan's initial digital footprint (specific blog posts are referenced in braces):

- **Detailed documentation of the making of guitar**. This spanned the motivations for, and history of the project {blog posts 1-3}, initial whiteboard sketches of possible designs {post 4}, details of knot-work {5}, guitar designs {8}, selection of woods, images of the build, reports from testing, discussions of craft techniques {10-22}, and time lapse videos of critical moments at which the soundboard and back were etched in the laser cutter {14} {17}.
- **Documentation of performances**. Renowned folk musician Tim Edey played Carolan at one of his concerts {35}. Tim used the guitar as a talking point within his performance, describing its concept and the music he was about to perform on it. Many other musicians also recorded songs and tunes to be added to Carolan's footprint.
- **New compositions**. Some musicians were inspired to compose new material on Carolan. Gypsy-jazz guitarist Lulo Reinhardt was inspired to compose a new tune for the guitar ('Catch the Moment') {27}.
- **Personal stories about guitars**. Carolan served as a probe for eliciting stories of guitar ownership. A guitar shop owner recounted stories of unusual guitars that he had bought and sold (and even had stolen and buried in a park!) over the years {33}. Lulo Reinhardt explained how he hand-decorated guitars and how he named his guitars after his grandchildren {27}. Jazz Guitarist Remi Harris was able to associate the patina on his guitars (the wear and tear resulting from repeated use or small bangs and scrapes) with memories of many hours spent practicing his technique or of particular accidents on stage {31}.
- **Notes on recording techniques**. We undertook two formal recording sessions with Carolan, the first at a home studio {38} and the second in a professional recital hall {41}. We captured both sessions including details of microphone placements, mixing and mastering that might serve to guide others on how to best capture Carolan's voice.
- **Maintenance history.** We documented various maintenance activities over this period, from routine string changes to a trip to the luthier for a reasonably extensive set-up that involved significant work on the bridge.

Figure 5: Tim Edey and Lulo Reinhardt

4. MAPPING GUITAR TO FOOTPRINT

A key challenge that emerged from this work concerned establishing a principled mapping between the various elements of this digital footprint and the interactive patterns that adorned the different surfaces of the guitar. While this remains an evolving mapping as the footprint continues to grow, the initial development phase established the following:

- Scanning the **headstock logo** takes the viewer to a digital version of a formal 'makers label' that conveys the guitar's official provenance (who designed and built it and why).
- The **front soundboard** was adopted to be the public face of the guitar, linking to curated selection of performance videos and highlighting those from well-known professional players.
- The **back** was given a more open treatment, being linked to players' own blogs. By default, this links to a list of all players, but might be configured to point at the current player's blog. As a physically large code, this is potentially scannable by some audience members if the guitar is displayed with its back to the audience, for example before or after the show or during the interval.
- As the main point of accessing the guitar for maintenance, the Artcode on the **removable soundhole** was mapped to a user guide that covered topics from how to control the pickup and change the battery to a compilation of tips on recording the guitar.
- The codes **under the strings** linked to technical information about Carolan's construction of interest to technicians.
- The **hidden code** in the cutaway was reserved for bonus materials, for example videos of songs and recordings with renowned players that were not available in any other way.

We are not claiming these as universal mappings for all guitars or even as a stable long-term mapping for the Carolan guitar. Indeed, we anticipate that mappings will change, possibly quite dynamically, according to the instrument's current owner, use, context and the content available in the evolving digital history. Rather, we offer them as example of the general kinds of mappings that might be relevant to augmenting an instrument with its social history, both in terms of the sorts of digital information that might be of interest, but also in terms of some general considerations on how to 'place' such information on the guitar.

Our early experience suggests the following mappings as a potentially useful starting point for design: link official provenance to the headstock; technical information to physical access points or under the strings; public information to larger public surfaces; and bonus information that can be discovered by those who take time to become familiar with the instrument to hidden nooks and crannies. We draw attention to the relationships between information, physical surfaces, the structure and use of the instrument and the different kinds of users (players, audiences and technicians) who might scan the guitar.

5. CONCLUSION

Building the Carolan guitar has enabled us to probe the question of how Internet of Things technologies might enhance the social lives of musical instruments beyond their ability to directly generate music. We conclude our paper by reflecting on the lessons learned so far and how these raise questions for further research.

First we have seen how even a conventional musical instrument such as an acoustic guitar may become associated with a rich digital footprint. Carolan's footprint encompasses its official provenance and history, documentation of its various players and their performances and stories, technical documentation and user guides and a maintenance history. We propose that such extended footprints might add value to instruments in several ways. Official provenance information is important for confirming the value of collectable (e.g., vintage or limited edition) instruments, while stories of use may add further value, especially when well known players are involved (we have already had one inquiry to buy "that guitar that Remi Harris played") but potentially also where they involve personal connections (e.g., inheriting a guitar from a friend or loved one). In turn, we have seen that technical documentation may extend beyond the usual details of operation to the nuances of producing or recording a particular sound. In terms of future research, it would be interesting to explore how this aspect of a footprint could become even richer for digital instruments with their potential for frequent reconfiguration and ability to digitally record their state and usage.

Second, we have demonstrated one particular way of attaching a footprint to an instrument – through interactive surface decoration. This has raised the question of whether there are generic principles for mapping different surfaces of an instrument to different facets of its footprint. How should a mapping account for the relationships between different potential users (players, technicians, audiences) and the structure of the instrument (the ready availability of surfaces in different contexts). Future research should explore the nature of such mappings for a wider range of instruments and consider other IoT technologies. For instance, what mappings would be appropriate when embedding electronic sensors into an instrument, or when considering a different form of instrument or even when designing an instrument from scratch?

Finally, reflection on this initial phase Carolan's life has raised a series of additional questions that we intend to explore in further research.

How might we more easily capture the footprint? Can we augment an instrument to capture as well as tell its story or to help crowdsource capture by inviting audiences to contribute?

How can players perform the footprint? How can the footprint be conjured up in a live setting and incorporated into a performance?

How might users personalize the mapping? Currently, all users experience the same mapping from the guitar to its footprint. Should the current owner be able to direct parts of the guitar to their own content (album, videos or website) or might it also link to contextual information (for example about the current venue or gig)?

How can we provide a legacy experience? The key consideration here is what happens when the instrument changes hands? Are all of the current owner's contributions to the footprint available to future users and conversely, how do they remain in contact with the instrument in the future? Is there a legacy experience (e.g., decorated guitar accessories such as plectrums and straps) that enables them to keep in contact with the instrument?

In our view, questions such as these lie at the heart of an emerging research agenda concerned with the design of 'social' musical instruments – or at least instruments that better connect to their social context of use – and can also help shape emerging IoT technologies, especially techniques for crafting interactive surface decoration.

6. ACKNOWLEDGEMENTS

We would like to acknowledge the following grants and thank the EPSRC. EP/J005215/1 Dream Fellowship: Inspiration, Immersion and Impact with the Creative Industries, and EP/L019981/1 Fusing Semantic and Audio Technologies for Intelligent Music Production and Consumption.

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