Where Few NIMEs Have Gone Before: Lessons in instrument design from Star Trek

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ABSTRACT

Since 1966 Star Trek has been exploring imaginary and futuristic worlds in which humanity comes in contact with alien cultures. Music has always been a method through which alien cultures are made relatable to humans, and musical instruments become props through which we learn about an alien culture that is totally different to that of humans. These musical instruments were not designed with musical use in mind; rather they are designed as storytelling devices, and never intended to work or make sound. After discovering one of these instruments I realised that recreating it in the way it was imagined *and* making it functional would require consideration of the instrument's storytelling function above all else, including the technology. In this paper I describe the process of re-creating an instrument from Star Trek as a functional DMI, a process in which design decisions were guided by what the storytelling intentions were for this imagined instrument, and what I found out by having to make technical choices that supported them (not the other way around). As well as reporting the design and implementation process I summarise the important design lesson that came from having to emphasise the intended mood and presence of an instrument, instead of the design being steered by technical affordances.

Author Keywords

instrument design, theory, DMIs

CCS Concepts

•**Applied computing** → **Sound and music computing;**

1. INTRODUCTION

Science fiction has profoundly impacted the way we imagine possible technological futures [17], but few influences are as enduring as that of the expansive universe of Star Trek. From possible medical treatments [11] and food production [8], to voice interfaces for computers [5] and methods of collaborative problem-solving [10], the world of Star Trek has been used for more than half a century as a place for imagining potential technological futures [9].

Figure 1: The finished instrument.

Star Trek is also a place for imagining future culture, both human and alien. In the Star Trek future humans have technology that enables space travel, and in keeping with the mission to "seek out new life and new civilisations" alien species are frequently encountered by the crew. Particularly in the series *Star Trek: The Original Series* (TOS), *Star Trek: The Next Generation* (TNG), and *Star Trek: Voyager* (Voyager), music was a method used by writers to demonstrate the alterity (or lack thereof) of aliens by contrasting their culture with that of humans. Musical instruments are an integral part of this, though these instruments aren't functional; rather, they are storytelling props with sound added later.

In 2020 I found myself watching a lot of Star Trek, and I was captivated by the alien instruments on the show. This was because the factors that guided the design of these objects were rooted in the culture that writers imagined had produced them. This struck me as a complete inverse from the DMI design process I always seem to find myself in, one in which the technology that drives the instrument becomes the factor with the most influence on design decisions. This outsized influence is because the technology that drives a DMI — how big it is, what it can do, how it's powered, what it can connect to, and how it produces sound — are so crucial. These Star Trek instruments were striking because they were imagined with no technology in mind, because they never had to actually work. Instead, their physical form and the sound they make are derived purely from the writer's storytelling intentions.

I decided to explore DMI design process from this perspective: by re-creating an instrument from the show, and

NIME'23, 31 May–2 June, 2023, Mexico City, Mexico.

giving it the functionality that the show proposed. This paper describes that process, from identifying an instrument, seeking out the original production designer, constructing the instrument, and how the intentions of the instrument's storytelling role guided my technical choices (and not the other way round). Finally, I share an important insight on DMI design that came from this experiment.

2. BACKGROUND

2.1 Music as a storytelling tool

Music serves several storytelling purposes in TOS, TNG and Voyager. Firstly, music is used to indicate superior intelligence: Many Starfleet members, as well as being scientific geniuses, also play instruments (for example Commander Riker plays the trombone, Captain Picard plays the penny whistle, Harry Kim plays the clarinet).

Secondly, music indicates humanity. In TNG Commander Data, an android, continuously tries to become "more human", and learning to play the violin is part of his journey from machine to more-than-machine (though at first his playing wasn't convincing to his human friends because his mastery was "too perfect" — a theme that, interestingly, also appears in contemporaneous DMI [6] and mechatronic instrument [7] discourse).

Thirdly, music is used to indicate the level of alterity of an alien culture, meaning how different from (or similar to) humans a given alien race is. Music was not the only method of indicating the degree of alterity (in TOS and TNG human-pet relationships were used similarly [13]), but music presents an alien species through their cultural activity, indicating that alien cultures are as sophisticated as that of humans (or, perhaps more accurately, sophisticated in the same way). This rich range of similarity and difference was one of Star Trek creator Gene Roddenberry's primary visions of the future and a primary theme in Star Trek: "If man survives that long, he will have learned to take a delight in the essential differences between men and between cultures. He will learn that differences in ideas and attitudes are a delight, part of life's exciting variety, not something to fear" [18, p 40].

2.2 Alien instruments

What is striking about musical instruments in Star Trek is that they are an elegant way of introducing the features of alien cultures that are relevant to a specific episode. Some examples:

TOS: Vulcan harp Exploring Vulcan culture is a common theme of TOS, and Vulcan instruments feature regularly. Spock plays the Vulcan harp which is a traditional Vulcan folk instrument, yet this harp also has knobs on it. This tells us something about Vulcans: not only do they have a complex and well established tradition of music (like humans), but they have also had sophisticated technology for millennia (far longer than humans).

TNG: Algolian instrument Ceremonial percussion rhythms played by an Algoian musician on a percussion instrument [2] are central to TNG Season 3 Episode 24 (*Ménage à Trois*). The instrument is composed of loose hanging strings of bones that produce percussive sound when struck with a hammer (how it makes sound is not explained). This suggests that Algolians are ritualistic, and have music traditions that are important ceremonially.

Voyager: Enaran Instrument Voyager Season 3 Episode 6 (*Remember*) features Enarans, a telepathic race, who play a musical instrument [3] with their minds (again, the mechanics are not explained). Their leader offers to teach Captain Janeway to play it, but when he does he establishes a telepathic connection with her, which leaves her shocked. The instrument is used to tell us that Enarans' telepathic skills extend into every facet of culture, including leisure, and also that they can enter the minds of others with minimal effort. In stark contrast to humans, they don't consider this invasive.

2.3 The Aldean instrument

I was especially struck by one instrument in particular: The Aldean instrument, from TNG Season 1 Episode 17 (*When the Bough Breaks*) [1]. In this episode an alien race known as Aldeans kidnap the children of the Enterprise, because Aldeans have been unable reproduce they fear they'll die out. The children are distributed among families and a young human girl is sent to a family of musicians, where she's taught to play their instrument. This instrument only appears onscreen for mere moments, but has an intriguing combination of sophisticated physical design, and the episode provides some indication of how it produces sound: It is a disc-shaped object that the player lays their arm across, and grips the edge with their fingers, in order for the instrument to 'read their thoughts'. This instrument tells us about the Aldeans' relationship to music, as well as their highly attuned emotional skills. In the background of this musician's room there's also a Vulcan harp, suggesting that Aldeans are not only space faring and have contact with other alien races, but that they also incorporate other cultural tradition into their own.

Due to being so fascinated by the Aldean instrument I researched it, and learned that it's the only musical instrument in Star Trek that has a design credit: Andrew Probert, an influential science fiction concept designer. He is still working and I contacted him via his website [4], asking if he could tell me anything about the process of designing this instrument. He emailed me back shortly after, saying that he didn't remember much about this specific instrument, but that he had found and scanned his original production sketch and attached it if I was interested.

Armed with more detail than the Aldean instrument's seconds of screen time, I decided to recreate the instrument and give it the musical functionality it had in the show. As well as musical functionality, it had to also maintain

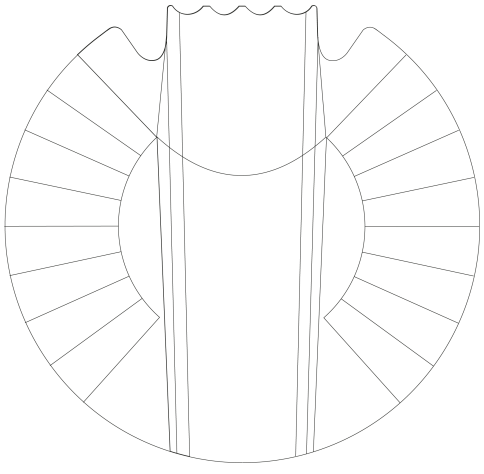

Figure 2: Cut lines for creating the instrument body.

the form, mood, and function that was required of it as a storytelling prop.

3. BUILD PROCESS

I went through the process of recreating this instrument with the requirements of the original in mind: It had to be disc-shaped, it needed to be held and activated by touch, it had to glow when played, and it had to translate thoughts (a nice tinkly sound if the player was calm, and jarring noise if it sensed they weren't).

3.1 Physical build

One of the biggest challenges of this build was staying true to the instrument's original mood, while having only a moment on screen and a concept sketch to go on.

I created the body of the instrument by laser cutting layers of board and adhering them together, which allowed me to build up the instrument while also adding design details that made it look like a designed object, and not just a laser cutting exercise. I designed the shape of the instrument by dividing a circle into component parts and determining the cut lines (see Figure 2). Then I cut these component parts and assembled them together, varying their heights to create some visual interest.

The lights were added by creating an acrylic enclosure covered with coloured caps (made by layering transparent paper onto acetate sheets with matte medium until they were as diffuse as required, and then attaching these caps to each light assembly with transparent adhesive).

The hand grip was challenging, as it had to suggest where and how to place one's hand (with the fingers wrapping around the edge), as this was the only method of activation. I created a curve by layering and offsetting laser cut parts in order to create a grip curve (see Figure 3).

The final stage was thinking about what decorative design features the object might have, and how these might could align with the original design intention. This was designed as an instrument used by an alien species with a very sophisticated and well-established music culture, so I decided that it would be unlikely to be spartan. I added some decorative pieces on the arm channel and some detailing at the back to give the instrument the kind of visual interest that is added by, for example, scrolling on the head of a violin (see Figure **??**).

3.2 Interaction

The instrument in the episode is said to "translate thoughts". It's not said that it reads minds, but rather that it expresses one's thoughts through sound. But, as this was an exercise in recreating this instrument's design and function as faithfully as I could to what was in the show, I considered how far this instrument's original intentions wandered into the arena of affective computing. Affective computing, defined by its originator Rosalind Picard as "computing that relates to, arises from, or deliberately influences emotions" [15] — in other words, trying to make computers recognise and respond to emotions.

While affective computing is concerned with understanding, recoginsing and responding to the full range of human emotions (as imagined as some combination of both physical arousal and emotional valence)[16], the emotional range of this instrument as it appears in the story is more limited. In the episode this sensing seemed to be of calmness; even though the girl playing it had just been kidnapped it didn't express a sound that seemed to be anxious or afraid. Instead, the only two modes it seemed to sense were calmness (which it responded to by playing a chord of sparkly noise) and sudden movement (which it translated as a burst of discordant noise). While there was no suggestion that the instrument is telepathic, and though it only had two basic modes in the show, there was still the challenge of determining how to sense these two modes.

3.2.1 A lesson from Instagram

In the weeks that I spent mulling this I happened to log into Instagram using the browser-based version of the app. While typing a message I dropped my phone, and when I picked it up the browser was displaying an error message saying that it had detected a "rage shake" (see Figure 4). Leaving aside the worrying fact that this app's parent company was clearly monitoring the accelerometer in my phone, as well as the bewildering conclusion that users most commonly respond to frustrating technology by shaking it, this was an example of a crude 'translating of thoughts' into action using sensing technology. This made sense: of course our bodies produce measurable physical responses to our varying internal states.

3.2.2 A thought-sensing system

Though I was only recreating these two basic responses (calmness, and excitement), I still had to decide how to use technology to sense these two states, and more importantly, how it could feel like *playing* the instrument, and not just keeping still or moving around.

I designed a sensing system using a Bela Mini [12] connected to an ADXL335 accelerometer, and Trill Bar touch sensor. This was to sense two axes of physical response: How much the player is moving, and how hard they're gripping the instrument.

Sensing motion

When the young girl learns to play this instrument she is scared when it begins reacting to her thoughts and drops it to the ground. When dropped the instrument made a loud clanging sound, suggesting that sudden movements are aligned with discordant thoughts.

In order to sense this discordant state I used the accelerometer to monitor incoming data on the X, Y and Z axes. The system continuously calculates the quantity of motion on each axis by Euclidean distance. By combining these readings I was able to experiment with a quantity of motion threshold over which the instrument would react with jarring noise. I kept this quite sensitive, as it was clear from the teacher that playing the instrument required maintaining a calm, meditative state.

Sensing grip

The hand placement on the instrument was the activation interaction, and the contact that brought the instrument to life. I decided to make this point of contact sensitive and precise, and also reactive not only to if it was touched, but how.

I used a Trill Bar for this touch interface, for several reasons. Firstly its form factor meant that it could be embedded under the grip for a seamless appearance exactly where the instrument needed one. Secondly, because Trill Bar it has the ability to sense up to five independent touches, I could add a dimension of interaction that meant the sound would be dependent on the number of touches present (up to four, one for each finger). Finally, Trill Bar senses touch

Figure 3: Left, hand grip; right, decorative detailing.

size, meaning that I could sense how hard someone was gripping the instrument — present touch sizes that were very small would mean they were lightly touching it, while large sizes would mean they were pressing down hard. I mapped the volume of each of the component voices to the touch size of each finger, so a harder grip meant the sound would be louder.

3.3 Combining sound and interaction

The sound design that is applied to this instrument in the episode is fairly basic (as is the case with most instruments in Star Trek). Though I had some ideas for more complex and interesting behaviours those are an extension of this instrument, and I turned my attention to recreating its original behaviour.

When the girl touches the instrument and is calm, the instrument's sound starts very gently and then grows into a chord of synthesized voices. It's a major chord with four component notes, so I re-created those component sounds in Ableton Live. I also created a sound for the noise state for when the instrument senses negative valence, which was a burst of noise.

The software for this instrument is in Pure Data. As the instrument is held still and each finger is placed on the Trill Bar, each of the samples are triggered, with four fingers completing the chord. A harder grip, sensed by touch size, increases the volume of each sound component by the size of the relevant touchpoint. In this way, the grip is not interpreted by the instrument as necessarily negative, but more intense, and the sound responds accordingly.

When the threshold for movement is overshot by the accelerometer's input, the chord stops and the noise burst is triggered at maximum volume. I shaped the noise sample more precisely with an envelope in Pure Data to achieve the exact effect.

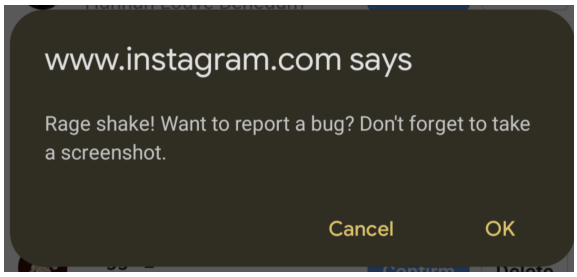

Figure 4: A very instructive error from Instagram. I didn't forget to take a screenshot.

4. OUTCOMES

4.1 Playing it

Due to Bela's high-performance data processing, the instrument's final configuration was surprisingly sensitive to touch and movement. It's not chaotic or hard to control, but it feels like it demands a certain intentional stillness. The Trill Bar worked better than expected, as it was not only able to be seamlessly integrated into the hand grip but also readily sensed the separate fingers and their touch size. I found myself trying to determine the right position to sit in and way to place my hand so I could reliably place my fingers on the sensor in the way I wanted, and play the component parts of the chord in the way and at the volume in what felt like the 'right' way. The instrument seemed to require a specific technique that wasn't difficult, but was specific and tied to the way I wanted it to sound and had room for stylistic variation.

The musical language of this instrument in this version is limited because the sound design it had on the show was very minimal, but I was surprised at the degree of sensitivity that these two sensing axes — motion and touch — offered. Moreover, recreating this crude sound design and playing it did give me insight into where else the sound design could go. The sound is based on a major chord, and though 12 tone equal temperament is currently extremely influential in certain areas of human music for a myriad of reasons [14], there's little reason to assume that it would be as prolific a few centuries hence (or that this method of tuning would extend its influence through multiple galaxies). A planned extension of this exercise is to develop a sonic language for this instrument that is free of any human presumptions of music but still communicates a range of emotional valence, such as sounds that are related to each other based purely on mathematical relationships and not any specific notion of 'tuning'.

4.2 Reflections and takeaways

This approach had an important and salient lesson: An instrument's cultural context, its life as an object that has a role and purpose in an artistic setting, provides more useful boundaries for instrument design than technical requirements or available technical affordances.

The process of re-creating this instrument provided an opportunity to depart from my own learned habits in DMI design, in which the technology involved was the weightiest factor guiding design choices. Instead, recreating a storytelling prop that was designed without technology in mind meant that the design decisions for both form and function would be guided by supporting and being faithful to the

Figure 5: The sensing system

storytelling function of the instrument.

Often when designing DMIs a sticking point is that design decisions feel unrooted in purpose. DMIs, by virtue of being digital, can sound like anything you can imagine, be virtually any size, and be made from any material. Therefore, the only meaningful constraint to hand is the technical aspects, because every technology has specific affordances and requirements. Even if we want to root our decisions in an instrument's context of use, there isn't necessarily one available. DMI performance is a highly experimental, decentralised, idiosyncratic and ever-evolving practice, and unless a DMI is for the designer's personal use there is usually no easily-identifiable and stable music tradition, repertoire or genre in which to root these decisions.

Some of the same can be said of the imaginary instruments of Star Trek. Like DMIs they also lack any kind of limitation on their form or what they're able to sound like (Star Trek is, after all, a utopian techno-future in which everything is possible and available). However, there is an important difference: Because of their function as storytelling props, they have a specific (albeit fictional) cultural context, and communicate specific things. Even if that context is entirely imaginary and only lightly described, there is certainly enough to consider how the instrument might exist within it and how it would be used.

Being forced to put the technology in the background and only implement what would bring a DMI to life on its own terms is a good exercise for any DMI creator, but this process threw into high relief the fact that understanding the way a DMI exists in the world is a far more useful place to root design decisions than the technology we might have available and what it can do. Though this is a useful process to carry out with other DMIs, it's hard to say how to best frame and understand the context or cultural meaning of DMIs given the current community engagement with this topic; despite some increased orientation towards cultural factors in the NIME community in recent years, there is still comparatively little discourse about the cultural function of the instruments we make, or even language to describe the precise combination of technical and artistic factors that DMIs embody. The implication is, therefore, that being able to fully understand and describe the cultural function of DMIs would provide a vitally useful set of criteria for design, rather than focusing on the technology used to build them.

5. CONCLUSION

This paper describes the process of re-creating a fictional instrument from Star Trek — not only creating the physical manifestation, but making it functional. I detailed the process of discovering the instrument, researching it, creating the physical housing, and designing the sensing system to read the two thought states depicted in the show. The result is a DMI that brings the instrument on screen to life, with a sensing system that, when the player touches the active hand grip sensor with their fingers, plays a twinkling chord that varies in loudness and intensity according to how hard the player grips the sensor, and produces a burst of noise if the player shakes or moves it suddenly. The instrument, even with this limited repertoire of sound possibilities, is interesting to play and requires a certain amount of technique, and it's opened new doors of considerations about where else the sound could be taken using this form factor and sensing system. The most important takeaway from this process is that an instrument's cultural context, its life as an object that has a role and purpose in an artistic setting, provides more useful boundaries for instrument design than technical requirements or available technical affordances.

6. ACKNOWLEDGMENTS

Thank you to: Andrew Probert, whose beautiful work has deeply inspired me and without whose generosity none of this would have happened; Chris Peck, for adjusting my tuning awareness; Pete Haughie, for his crucial Pure Data assistance; xHain Berlin, for their laser cutter, huge tables and excellent soldering irons; the Audio Developer Conference, for giving me the impetus to finish this thing; and Daniel Gabana, who continues to nudge me in all the right directions.

7. ETHICAL STANDARDS

This work is an empirical study and involved no research participants (human or otherwise).

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