# PlayShell: A Low-cost, Fun Audio Experience for Heritage Centres

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## ABSTRACT

Various barriers prevent blind and visually impaired people accessing the rich multisensory experiences available at heritage centres. These barriers include large bodies of text and items in glass cases, which are difficult to see. Feedback from the blind community reflects poorly upon the inflexibility of guided tours. Technology-based accessibility tools are often laden with visually heavy interfaces or require storage space or power at each exhibit.

This paper presents a low-cost digital audio guide that can be combined with existing 2D and 3D systems, as well as 3D printed reliefs and replicas. The technology aims to work in a variety of environments, allowing curators to retrofit it into centres with limited space. The handheld system provides pre-recorded audio to visitors as they explore the centre. Sound is triggered via 'tap' onto Near-Field Communication (NFC) tags, which are placed by the curator or artist. Content is updated via a central system, which replicates to each device. A storytelling process can be created through the addition of motion gestures (e.g. shake), enhancing the experience for all visitors.

## CCS CONCEPTS

• **Human-centered computing → Accessibility systems and tools**; • **Information systems → Personalization**.

## KEYWORDS

blind, visually impaired, NFC, IoT, audio tour, cultural heritage

## 1 INTRODUCTION

Visually impaired people often need escorts in places such as museums to relay information verbally and offer navigation aid [1, 7]. Nearly half of visually impaired people feel "completely" or "moderately" isolated [13]. Heritage and cultural centres can go some way to help solve the problem of isolation with multisensory learning experiences for everyone, including the visually impaired [10].

The UN's Universal Declaration of Human Rights (1948) states that "everyone has the right to rest and leisure" [11] and, in the UK, the Equality Act 2010 says that service providers should make "reasonable" adjustments for accessibility [6]. However, A study by Mesquita and Carneiro in 2016 explains that many heritage centres provide limited options for visually impaired visitors [10]. The study cites inaccessible objects, lack information or "improper attitudes on the part of [the] staff" [10].

Multisensory exploration "allow[s] a better perception of reality for blind people" [5]. The V&A Museum runs specialised touch sessions through the year and dedicated guided tours when pre-booked [4]. The Smithsonian offers two guided tours a month to provide "vivid descriptions" and interaction [4]. These solutions are limited, however. They must be pre-booked or planned and rely on a person for delivery. Reliance on a tour guide involves cost for the centres and restricts the visitor to the pace and delivery of the tour. Many centres use technology-based solutions as a cheaper alternative, but these systems are often laden with cumbersome, or highly visual, interfaces. This technology more commonly relies on visitors bringing their own smartphone or the centre offering some on a loan basis, adding to the development cost of the solution.

Heritage centres are increasingly losing their sources of funding, with funding in England dropping 13% between 2007 and 2017, and some areas faced with a 40% reduction [8, 14]. This cost-cutting leaves centres with a choice of where to reduce spending, and most (63%) choosing to reduce the quality of their exhibitions [12].

In this paper, we introduce **PlayShell** an Internet-of-Things (IoT) audio device, a low-cost, non-intrusive, audio tour guide suitable for all types of heritage centre, with a particular focus on accessibility. **PlayShell** is a fun, interactive and tactile device for everyone, that aims to eliminate many of the barriers visually impaired visitors face by removing visual interfaces while allowing centres to easily add sound archive material and audio descriptions to existing artefacts. The system moves away from special-purpose accessibility tools to an interactive tour guide that everyone can enjoy.

The remainder of this paper is structured as follows: Section 2 covers related work; Section 3 gives an overview of **PlayShell** and considers the visitor's experiences in the context of the application design; and finally Section 4 concludes with pointers to future work.

## 2 RELATED WORK

The Metropolitan Museum of Art uses iPod Touch players for their interactive tour guide, where visitors read a code from the exhibit and type into the keypad on the iPod to access content [9]. Mann and Tung [9] evaluate the effectiveness of the systems commenting that many visitors find the complex lettering system challenging to understand, though visitors persist with the interface in an attempt to learn more about the artefacts and to make the experience more entertaining.

Cliffe et al. [3] present The Audible Artefact, a smartphone-based system which provides camera-based tracking to provide audio. Their system uses object detection from the camera to locate the user and play sounds relevant to the object. Zimmermann and Lorenz's LISTEN [16] uses an indoor positioning system (IPS) to automatically play 3D sound. In contrast to The Audible Artefact, LISTEN removes all elements of a visual interface by automatically triggering sound based on the wearer's location and head orientation. Visitors select a category of content (fact-orientated;

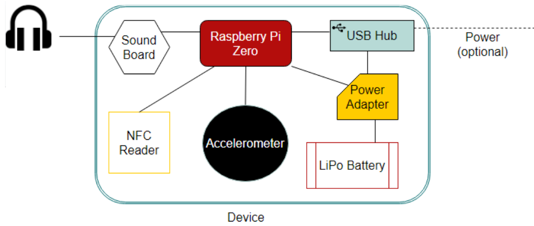


**Figure 1: Abstraction of audio device hardware**

emotional; or overview) upon arrival. Like LISTEN, our focus is to remove line-of-sight visual elements though we give the visitor customisation options on an object-by-object basis.

Ceipidor et al. [2] use QR codes to provide a simple museum-based scavenger-hunt where participants install an app on their own smartphones and use the built-in camera to capture QR codes as triggers for the game content. QR codes do not rely on a network of carefully placed transmitters and receivers to operate and do not require much alteration of existing exhibits. Swedberg [15] follows a similar non-intrusive approach but removes the visual alignment accuracy of the camera to QR code by using NFC tags instead. In this implementation, visitors are directed to a website upon scanning of the tag where content that is not available on the signage is presented. D'Agnano et al's TooTeko system [5] embeds NFC tags under raised tactile surfaces, where its users wear an NFC-enabled ring with a Bluetooth transmitter. The ring transmits the tag's ID to the connected smartphone which streams audio and video content to the user. Like these systems, **PlayShell** offers non-intrusive trigger points by using NFC tags which can be affixed to displays or embedded within 3D objects but does not require participants or centre to own, potentially expensive and visually reliant, smartphones.

## 3 SYSTEM OVERVIEW

Two systems make **PlayShell**[1]: One acts as a centralised server for centre staff to manage the audio content and associations with NFC tags; the other is responsible for playing the audio for the visitor, running on the audio tour guide device. Audio content is synchronised from the centralised server to each audio device. Visitors take a device around the heritage centre to interact with exhibits that have been fitted with the NFC tags, triggering audio playback.

### 3.1 The Audio Device

Figure 1, shows an abstraction of the audio device, which is composed of a Raspberry Pi Zero W, RFID RC522 reader, MPU6050 accelerometer, PiSugar LiPo battery and management board, and a custom-made soundboard (in the absence of a built-in 3.5mm audio jack on the Pi). The Raspberry Pi Zero W is the smallest of the Pi family, measuring 66.0mm x 30.5mm x 5.0mm. The Pi consists of a 1GHz Broadcom BCM2835 processor with 512Mb RAM, 802.11n LAN and Bluetooth 4.0 connectivity. The RC522 reader operates on the 13.56MHz frequency and reads ISO 14443A standard tags. The MPU6050 accelerometer can detect X, Y and Z axis changes as well as a full-scale range of ±2g, ±4g, ±8g and ±16g. The PiSugar system is made to fit directly onto the Pi Zero and provides power directly to the pads on the bottom of the Pi. It contains four LEDs providing the status of remaining power and charges over micro-USB. We use the 900mAh battery for testing, but it does come as a 1200mAh version. The soundboard is a one-transistor mono amplifier compiled on a custom PCB board and powered from the Pi's 5V GPIO pin. Figure 2 shows an early version of the assembled hardware. The components cost just under £75, £125 cheaper than the latest iPod Touch from Apple, an alternative audio tour guide option [9].

Rather than embedding technology into exhibits, visitors carry the device. This method saves the need for power supplies, which becomes problematic in outdoor spaces, and reduces requirements for physical space at each exhibit, which is especially useful for preserved areas such as historical homes. As the device is handheld, we use physical interactions (motion gestures) to add another layer of visitor engagement in the hope that **PlayShell** becomes a standard piece of equipment for all visitors rather than an accessibility tool for a specific demographic. Our future work plans to explore this area further.

The hardware can be housed in a simple box to keep costs down, or a custom-made case in a style to match the centre's theme. For example, a centre based around medical history could use a 3D printed stethoscope. Figure 3, shows an initial cardboard prototype and a later 3D printed version.

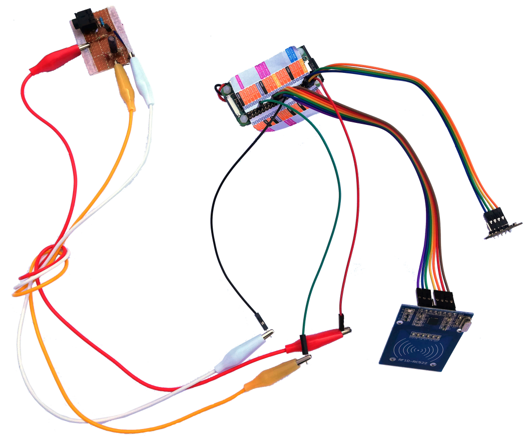

**Figure 2: An early version of the audio device hardware**

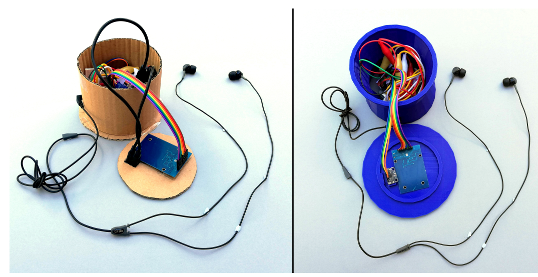

**Figure 3: Sample 'stethoscope' housing**

[1] https://github.com/pgoddard10/PlayShell

The transmission range of NFC tags is around 4cm between the tag and radio receiver, providing some flexibility in the precision from the user yet still maintaining a level of accuracy. Power for the data transfer to take place is provided from the RC522 reader, meaning that the tags have no battery or mains power requirements.

When the visitor taps the NFC reader against a tag with audio associated to it, the audio plays. If a physical gesture has been pre-programmed to happen after the playback, the device prompts the visitor with an audio cue and waits for its performance, followed by further audio playback. This loop continues until the visitor finishes with the device and returns it to the centre's reception for charging and synchronisation with the central system.

## 3.2 Managing the Audio Content

A system for managing the NFC tags and associated audio content has also been created. This system compromises of a Raspberry Pi 4 (Model B) and another RFID RC522 reader, costing just under £50. Sporting a 1.5GHz Broadcom BCM2711 processor with up to 4Gb RAM (2Gb in our case), 802.11ac LAN and Bluetooth 5.0 connectivity, this device is faster than the Pi Zero. The software is designed with a web-based interface to allow the centre's staff access via their existing computers. The Pi 4 also offers four USB-A ports and two micro HDMI ports, allowing the centre's staff to connect a monitor, keyboard, and mouse to alternatively access the interface.

The software handles the linking of tags with sound and gestures, as well as synchronisation of content from the central system to each audio device. Centre staff can upload sound files, such as sound archive material, recordings of voice actors and sound effects, or use the built-in text-to-speech (TTS) engine to create audio on-the-fly as shown in Figure 4. Utilising TTS instead of hiring voice actors can help with the centre's budgeting. We chose SVOX's Pico TTS[2] as it is free to use, works offline and can convert text to Waveform Audio File Format (.wav). Working offline allows centres without internet to operate the system and reduces reliance on an API which might change or break in a future release. The TTS system turns typed text that the centre staff create into spoken sentences to play aloud via the audio device. While the TTS engine used sounds like computer-generated audio, the voice is clear enough to understand. Future work will analyse the voice effects further.

Once the content is ready, the system copies the data over standard 802.11 WiFi to each audio device, which automatically updates its database and becomes ready for visitors to take around the centre. There is no limit to the number of tags per exhibit, or centre, leaving flexibility for the centre to choose which exhibits, and how many, work with this solution. Figure 5 shows an abstraction of the synchronisation.

A record of which items the visitor interacted with is transferred to the centralised system at the end of the visit. If the visitor has provided their email address, the system sends an email summary of the written text stored in the management system for later reflection.

## 3.3 NFC Tags

We use round NFC stickers, 29mm in diameter, (Figure 6) affixed to a variety of surfaces both indoors and outdoors or embedded

[2] https://duncan3dc.github.io/speaker/providers/picotts/

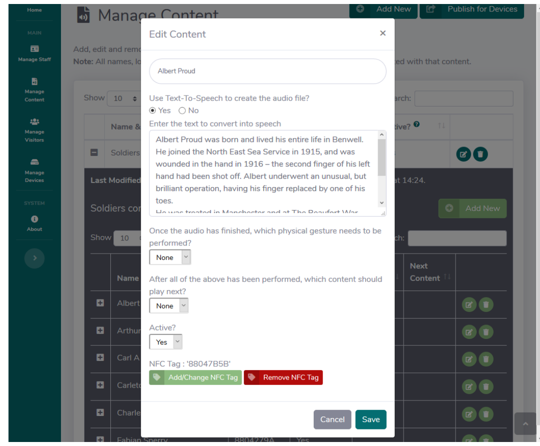


**Figure 4: Management system: Adding text-to-speech**

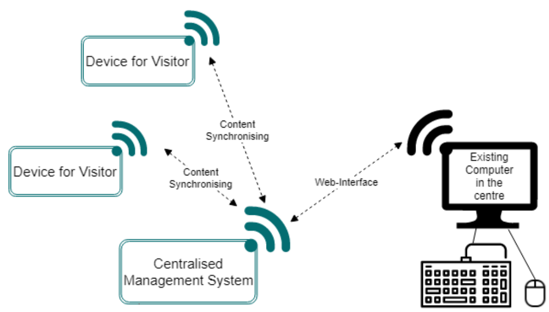


**Figure 5: Abstraction of data synchronisation**

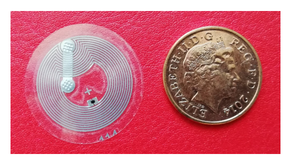

**Figure 6: NFC sticker size compared to a penny**


**Figure 7: 3D printed textured tile with embedded NFC tag**

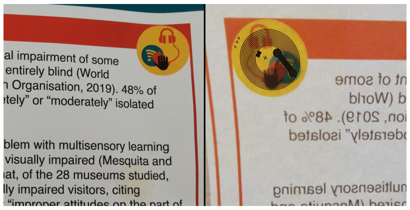


**Figure 8: Back and front of a poster with affixed NFC sticker**

within objects. These tags cost about £0.40 each. Any NFC tags compatible with the ISO 14443A standard work, although the transmission range directly relates to antenna size. Our experiments embedding tags under the surface of air-dry clay, Jesmonite and 3D printed objects (using PLA) were all successful if the 4cm range was observed. Figure 7 shows one of our 3D printed tactile reliefs, with a corner dedicated to the NFC tag, enabling a detailed audio description of the content of the tile. This prototype successfully demonstrates that simple 3D prints can offer multisensory experiences and opens the door to more complex 3D models with multiple NFC tags positioned throughout.

The small size of the NFC tags means existing displays can be retrofitted with tags, and in the case of large bodies of text, multiple tags allowing categorisation of information e.g. item descriptions, history. Figure 8 shows an NFC tag stuck to the back of a poster display and an example icon to indicate the tag's location.

## 4 CONCLUSION

This paper presented an alternative to the highly visual audio tour guides widely used in heritage centres. We have introduced a new level of visitor engagement using physical interactions with the device, captured by an accelerometer. By using low-cost Internet-of-Things technology, we have been able to create a scalable system able to offer a significant degree of flexibility to the centre. The system is complete with a content management tool for the centre staff to add and adapt the audio content themselves via a TTS engine, without any technical skills nor costly voice actors.

Focus groups and beta testing trials were ethically approved, but these sessions have been postponed due to the COVID-19 pandemic.

In future work, we intend to evaluate the effectiveness of this system within a range of heritage centres, specifically low budget museums. Working with all visitor demographics, including the blind community, is vital for this stage of our research. These groups can also help us explore the effect of its output, such as speed and tone. Another aim of our future work is to further reduce the cost and size of the solution by stacking all components instead of using wires for their connection, for example.

## 5 ACKNOWLEDGMENTS

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