Réaltacht: Creating Immersive and Accessible Experiences of Irish Traditional Music in Virtual Reality

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***Abstract*—In this article we report work in progress on an interactive immersive experience that brings several recordings of live music performances in the Irish tradition to virtual reality (VR) headsets and online 360° streaming. Using 360° green screen technology we virtually locate the musicians in three well-known cultural institutions of Ireland including a traditional pub, a former church repurposed as an arts centre and Siamsa Tíre - The National Folk Theatre of Ireland. Immersive audio is achieved using close-miking techniques, virtual ambisonics and impulse response captures of the reverberant destination spaces. We discuss the wider motivations of the project in the context of inclusive and accessible concert attendance as well as cultural heritage. The production pipeline is described, from inception and design to studio and venue capture followed by VR post-production, implementation and next steps.**

***Index Terms*—virtual reality, ambisonics, digital cultural heritage, irish traditional music**

I. Introduction

Despite its small geographical size and population, Ireland boasts a rich and expansive cultural heritage [1] that includes pre-Christian Celtic mythology arts and crafts, a wealth of literature in Irish [2] and English [3] languages, ancient Gaelic games and Viking and Christian influences. But perhaps it is its traditional folk music and dance that are the most widely recognised and exported worldwide [4]–[6].

Traditional Irish music is an oral tradition that has been preserved and developed over generations, musicians learn tunes and songs by ear and then perform them, often adding their own interpretations and variations. This continuous process of listening, learning, and sharing has kept the tradition alive and vibrant, while also allowing it to evolve and adapt over time.

The repertoire of traditional Irish music includes various types of dance tunes, such as jigs, reels, hornpipes, polkas, along with slow airs and ballads written in Irish and English [4]. Irish traditional music is predominantly monophonic, meaning that it is composed of a single melodic line without harmony or counterpoint. As the tradition evolved and adapted global influences, harmonic accompaniment was introduced through guitars, pianos or even the Greek bouzouki. Instruments native to Ireland include the iconic Celtic harp, the bodhrán hand drum, and the uilleann pipes, so called because they are played with the elbow (uilleann is the Irish word for elbow). Ireland has successfully inscribed the arts of Irish harping and Uilleann Piping to the UNESCO Representative List of Intangible Cultural Heritage of Humanity in 2017 and 2019 respectively, recognising and securing the importance of these instruments and their music as works of cultural diversity and creative expression [7], [8].

The European Union recognises the importance of cultural heritage in its member states, and the Horizon Europe funding structure aims to support its preservation and promotion within the context of a broader program focused on culture, creativity, and inclusive society [9]. Digital technologies play a crucial role in the preservation and dissemination of cultural heritage, enabling innovative ways to engage with and safeguard it for future generations. Immersive technologies in particular offer innovative ways to engage with cultural heritage and provide unique experiences that were not possible in the past [10]–[12]. Furthermore, immersive technologies allow inclusive and accessible virtual concert experiences for those groups who may be excluded from physical attendance due to disability, geography, age, or financial constraints [13]–[15].

This paper introduces the potential of VR in enabling immersive cultural heritage experiences of traditional Irish music performances. Three performances of traditional Irish tunes are recorded by an ensemble in a green screen studio environment using a Insta360 Pro 2 360° VR camera[1] and close-miking. We then visited three well-known cultural venues and captured the locations visually using the 360° camera and aurally using impulse responses to get a snapshot of the reverberant space. These venues included The Corner House, a well-known traditional pub famous for folk music concerts and sessions; Triskel Christchurch, a former neo-Georgian church built on the site of an ancient Viking Christchurch repurposed into an arts centre and Siamsa Tíre, a national folk theatre specialising in arts practices from Irish folk culture.

Through a VR production described in the following methodology section, the traditional Irish music performances were published as a 360° interactive application, ready for

[1] https://www.insta360.com/product/insta360-pro2

online streaming[2] on websites platforms like Itch.io[3], Simmer.io[4] or transfer to inexpensive VR headsets. With the combination of both 360° video footage and ambisonic [16] spatial audio recordings, the user can explore and interact with the virtual environments in every direction, where audio feedback dynamically changes as they move. We aim to deliver a realistic experience for end-users, replicating audiences' natural interactions and their perceptions of audio within these cultural music venues. Using a VR handheld motion controller, the user can select from a menu of options where they can teleport between three 360° VR cultural environments (Figure 1).

II. Previous Work

With the advancement of extended reality (XR) technologies and growing availability of 360° videos with spatial audio, there are now many opportunities for entertainment, cultural and heritage domains to deliver musical content through immersive VR devices. Turchet [17], in the context of the Internet of Things and Extended Reality, describes the "Musical Metaverse" (MM), as *"the metaverse part which is dedicated to musical activities, [and] is currently in its infancy, although is a concept that is constantly evolving and is progressing at a steady pace"*. The article provides a comprehensive survey of state of the art works in areas such as composition, education, performance, entertainment and sound engineering.

There are a number of articles in literature that outline the end-to-end production process for immersive captures of Western classical music and popular music performances.

Kentgens et al. [18] use the Eigenmike SMA to capture up to 4th order (25 channels) of spherical audio along with 360° video of the Aachen Symphony Orchestra's rendition of Gustav Mahler's 2nd Symphony. Overall, positive qualitative feedback was elicited from "expert and non-expert listeners" but there is no more information given on the sample participants. Bates and Boland [19] examine the capture of 360° video and audio experiences in contemporary music compositions that employ spatialisation more explicitly. They discuss the creative possibilities and challenges posed by ambisonic microphones and their placement, post-production dynamics processing and equalisation; and soundscape design. Holm et al. [20] take a quantitative approach to gauging 20 participants' experiences of 360° videos of Finnish rock music, comparing headset music consumption to more passive listening habits.

360° videos with spatial audio for general public consumption have been produced by well-known performers including the Los Angeles Philharmonic Orchestra's "Orchestra VR" which was a 360° 3D performance featuring the opening of Beethoven's Fifth Symphony [21]. Bjork's VR real-time music video "NotGet" [22] uses 360° video and spatial audio, which immerses the viewer to explore underwater while listening to spatial audio. There are many other popular examples of music concerts [23] that include 360° video and spatial audio including Metallica, Billie Eilish, and Coldplay's "A Head full of Dreams" concert film [24].

III. Methodology

In this section we describe the end-to-end production pipeline comprising pre-production, green screen 360° recording of live musicians, audiovisual capture of the target venues using a 360° camera and impulse response recording, concluding with the post-production combination and rendering of the final assets into a usable VR experience. The nature of this project was inherently multidisciplinary, involving distributed teams and skill sets spread across different locations in the South-West region of Ireland. Through a series of both in-person and online workshops the team engaged in a series of collaborative activities, including requirements gathering, ideation, and prototyping and testing. These efforts facilitated the evolution of ideas and validation of proposed VR production approaches. To foster multidisciplinary cooperation and streamline the planning and production processes, we leveraged participatory co-design methodologies and online collaboration tools, such as Miro[5].

A. Pre-production and Planning

A pre-production meeting was held at the green screen studio with the production team and a representative from the music ensemble to inspect the location and take measurements. The space was tested acoustically with the representative playing some tunes on the fiddle. It was decided to close mic each of the three fiddles with Sennheiser MKE2[6] sub-miniature omni-directional clip-on lavalier microphones placed discreetly near the fiddle bridges then connected wirelessly to the recording rig to reduce room noise and eliminate any visual wiring disrupting the green screen capture.

B. Green Screen Recording

The 360° video and audio recordings were captured in a green screen equipped studio set up for optimal chroma key production. The Extended Reality lab includes a 4m x 4m x 2.5m truss setup to which green screen backdrops and lights are attached (Figure 1 – Top). The setup was configured and tested to achieve even and consistent lighting. A Digital Multiplex (DMX) lighting control system was used for remote control of the lighting setup.

To capture the musical performances, the 360° camera was mounted on a tripod and placed 1.5 meters away at eye level with the performers. The performers were spaced apart adequately to allow for post-production adjustments such as stitching, cropping, or resizing. The video was recorded in 4K resolution and H.264 format, delivering good quality while considering file sizes.

To achieve accurate post-production compositing, the 360° recordings were captured at the three cultural venues by replicating the same positions and distances used during the

[2] anon-url
[3] https://itch.io/
[4] https://simmer.io/
[5] https://miro.com/
[6] https://en-ie.sennheiser.com/clip-on-lavalier-microphone-live-speech-instrument-mke-2

Fig. 1. Green Screen Recording (top) and final VR render (bottom)

recording of the performers at the Extended Reality lab. This was achieved by taking measurements and placing markers on the floor to provide a reference for the performers' positions, ensuring they were placed at a distance of 1.5 meters from the 360° camera. By doing so, the compositing process could be carried out seamlessly, with consistency maintained across all recordings from the different venues

The audio recording rig was setup before the musicians arrived to minimise disruption and ensure smooth operation. Signals from the wireless units were connected to a Tascam US-16x08 [7] audio interface and MacBook running the Reaper[8] Digital Audio Workstation (DAW) at 24-bit depth, 48KHz sampling rate and line checked for signal. Stools were placed in a semi-circular pattern at anticipated seating points for each musician and the camera was placed 1.5 metres back in the centre of the semi-circle.

When the musicians arrived seats and camera positioning were adjusted for their comfort and visibility of each other. The microphones were attached to the bridges of the fiddles of each performer and the radio units were discreetly hidden from view of the camera on their bodies. Microphone preamp gain levels were adjusted for best signal and maximum headroom. The musicians decided to record three sets of tunes that included a set of polkas, a set of reels and a slow air composed by one member of the ensemble. A set of tunes comprises several individual tunes within a particular dance style grouped together one after another. The musicians recorded several takes of each set of tunes and indicated to the production team which take they preferred and would like to use in the next stages of production.

[7]https://www.tascam.eu/en/us-16x08
[8]https://www.reaper.fm/

C. Venue Capture

The first target venue at which we captured audiovisual characteristics was the Corner House pub in the centre of Cork City. Well-known and highly regarded as a venue for traditional Irish sessions since 1985, this establishment is typical of many traditional pubs, with wood flooring, medieval stone walls and a fireplace in the corner. Lighting conditions are dim and intimate throughout the building except for the rear which has a slightly raised stage and skylight for bigger more formal, audience-facing concert performances.

With the kind permission of the owners, we secured access to the venue one morning before they opened to the public. After inspecting the room for the best location to virtually position the musicians, we set up stools on the stage in an identical arrangement to the green studio and set up the 360° camera facing them using the same measurements. We stepped out of the field view of the lens and set the camera recording, which only took 60 seconds or so.

Once satisfied with the video capture, we were ready to carry out the impulse response capture. The position of the camera was marked out on the floor then it and the tripod were packed away safely. We set up several microphone stands at the marked position to experiment with different patterns. For playback of the impulse a single Yamaha HS8M monitor was positioned at the centre point of the arc where the musicians are seated to simulate their source points. We experimented with two condenser microphones – an Aston

Spirit[9] and an Oktavia MK12[10] – set to omni-directional and cardioid polar patterns respectively. The microphones and speaker were connected to a Behringer UMC1820[11] interface and MacBook computer. There are numerous methods and software packages for creating impulses and sweep files for generating impulses responses, but we used the freely available IR Convolution Reverb Sweep File provided by the plugin manufacturer Waves[12]. Using a consumer sound pressure level meter, we tested the signal for around 80-100dB and calibrated the microphone preamplifier gain to ensure sufficient dynamic range headroom. Three impulse response recordings were taken for safety. One difficulty encountered on the day was the heavy construction taking place directly outside the venue, so we needed to time our captures carefully to ensure as little background noise as possible.

This entire process was repeated at the other two venues. Since these locations were much larger spaces, we did three separate captures: near to the stage, far away from the stage and at the midpoint. In the case of the Triskel Christchurch, it being a repurposed church we took the capture at the stage, along the nave and on the balcony to the rear of the building. In the case of Siamsa Tíre, the points we chose were in the audience seating.

At Siamsa Tíre we additionally had access to a Sennheiser AMBEO VR microphone[13] allowing the capture of a impulse response of a static source in full 360° spatial audio using ambisonics. This microphone uses 4 matched capsules arranged in a tetrahedral format to enable 360° ambisonics recording in four channel A-Format. Using the manufacturer's A-B encoder these channels are converted into the W, X, Y, Z B-format signal. Ambisonic recording using microphone capsules arranged in this pattern is very sensitive to signal level differences, so it is important to calibrate each of the microphone preamplifier gains to the same level. Many high-end portable recorders such as the Sound Devices MixPre-6 II[14] have digitally controlled preamps that can link each gain input for precise and consistent control. Unfortunately, the Tascam US-16x08 recording interface we had on the day had no such features, so the preamps had to be calibrated manually. Following a method outlined by Berklee Online [25], we connected a cable from one of the spare outputs to each input in turn and fed in a pink noise signal. We set the gain to a set level, anticipating sufficient dynamic range headroom for the actual microphone and live recording.

D. Post-Production

With all recordings complete, we labelled all the session files and assets carefully and copied them to a SharePoint folder for collaboration and backup purposes. The postproduction process comprised three stages:

1) Import 360° capture of the venues into the background of the scene
2) Remove green screen backgrounds from the recordings of the performers and stitch onto the background scene
3) Convolve recorded audio tracks with the appropriate impulse response for each venue and position each track as ambisonic audio sources corresponding to each position of the individual performers

We experimented with two different approaches to producing the VR visual scene using the 3DVista Virtual Tour Pro package and the Unity game engine. 3DVista[15] is a user-friendly "no-code" editor for creating and rendering 360° virtual tours that has been used effectively by others in cultural heritage projects exploiting VR [26]–[28]. Unity 3D [29] is a multi-platform game engine for rapid creation of 3D scenes, with an intuitive WYSIWG interface and a large marketplace of addons, assets and tools. In the discussion section, we reflect on the advantages and disadvantages of each method.

1) 3DVista Workflow: The 360° video of the musicians performance captured in the green screen studio and the three 360° videos of the music venues were imported into Adobe Premiere Pro for stitching. The 360° video green screen footage was cropped then chroma keyed to remove the background. As the footage was captured in three locations all with different light sources, the green screened footage had to be colour graded three times to match the different light sources.

After editing and colour grading were completed the green screen footage had to be overlaid onto the three locations. In order for the chroma keyed 360° video of the musicians to look authentic in each location, positioning and precision resizing of the green screened footage was carried out. The three 360° videos were then exported from Adobe Premiere Pro at very high bit-rates to ensure the highest quality possible for viewing in a VR headset.

The 360° videos were then imported to 3DVista a professional virtual tour software for creating rich media portals and apps, interactive training and virtual showrooms. Panoramic 360° images were added to create an interactive landing page for the app. Custom graphics were created for the user interface (UI) and used as hotspots inside 3DVista to create a fully immersive 360° VR experience to allow the viewer to navigate between the three locations. The published apps from 3DVista can be viewed on any desktop, laptop and VR headsets.

2) Unity Game Engine Workflow: Unity 3D Unity supports 360° video playback and can be used to create immersive and interactive VR experiences using 360° videos. Developers can use the Unity 360° video playback feature to create a 360° video player, which can be used to play back 360° videos in VR. Unity also includes tools for creating interactive environments, such as hotspots, which can be used to trigger actions when users interact with specific areas of the video.

[9]https://www.astonmics.com/EN/product/mics/spirit

[10]https://www.oktava-shop.com/Small-and-medium-diaphragm-condenser-mics/Oktava-MK-012-01.html

[11]https://www.behringer.com/product.html?modelCode=P0B2J

[12]https://www.waves.com/downloads/ir-convolution-reverb-sweep-file

[13]https://en-ie.sennheiser.com/microphone-3d-audio-ambeo-vr-mic

[14]https://www.sounddevices.com/product/mixpre-6-ii/

[15]https://www.3dvista.com/en/products/virtualtour

The 360° videos were imported into the Unity package as a media asset. For each target venue, we created a render texture using the corresponding 360° video file. Next materials are created for each target venue and the render texture videos are applied to create a Skybox background that envelopes the 3D scene, simulating the effect of being in the room.

With the visual scene rigged up, we then imported the mastered audio tracks to Unity and set up "Audio Source" game objects to position them spatially within the 3D scene. Unity allows setting audio sources as ambisonic with a spatial blend parameter setting the desired balance between 2D and 3D audio playback. The Unity documentation states, "Morphing between the 2 modes is useful for sounds that should be progressively heard as normal 2D sounds the closer they are to the listener" [30].With the basic audiovisual experience in place we then created an interface to allow the user to select which of the venues they wish to experience. Unity can be extended with scripting in the Mono flavour of C#, and a simple handler object was added to a visual game object allowing the user to select which of the venues and associated audio track they wish to view.

IV. Next Steps

We demonstrated the work in progress to over 80 staff and students at each campus of the Munster Technological University during a month-long programme of events celebrating innovative projects and collaboration. Informal feedback was encouraging and positive, and we intend to follow up with those participants who agreed to perform a formal evaluation of the immersiveness and *presence* of the experience adapting methodologies proposed by [31]–[33]. In tandem, we are working on a new experience that will combine traditional music performance with *sean nós* (old style) dancing using audio capture of a solo musician along with the dancers tapped footsteps.

Acknowledgements

We thank Johnny McCarthy and the members of the Bruach ensemble for their musical performances.

We also thank The Corner House, Triskel Christchurch and Siamsa Tíre - The National Folk Theatre of Ireland - for the kind use of their venues.

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