

Virtual Play in Free-viewpoint Video: Reinterpreting Samuel Beckett for Virtual Reality

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ABSTRACT

Since the early years of the twenty-first century, the performing arts have been party to an increasing number of digital media projects that bring renewed attention to questions about, on one hand, new working processes involving capture and distribution techniques, and on the other hand, how particular works—with bespoke hard and software—can exert an efficacy over how work is created by the artist/producer or received by the audience. The evolution of author/audience criteria demand that digital arts practice modify aesthetic and storytelling strategies, to types that are more appropriate to communicating ideas over interactive digital networks, wherein AR/VR technologies are rapidly becoming the dominant interface. This project explores these redefined criteria through a reimagining of Samuel Beckett's *Play* (1963) for digital culture. This paper offers an account of the working processes, the aesthetic and technical considerations that guide artistic decisions and how we attempt to place the overall work in the state of the art.

Index Terms: J.5 [Computer Applications]: Arts and Humanities—Performing Arts; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality

1 INTRODUCTION

There are many new digital tools for inscription and image capture, which are improving in terms of speed, clarity and resolution, and therefore realism¹. New capture techniques provide opportunities for augmented rendering of gestural, biometric and corporeal information in new, innovative and spectacular ways, as well as accessing, studying, interpreting and reflecting upon visual/performing arts practice and reception. Accompanying these new paradigms are also new questions relating to authorship and the extent to which digitally-engaged performance is a mutable process, concerning the convergence of a number of human and non-human (technological) subjective forces. These performative² assemblages (*agencements*³) may concern, but are not limited to: performance artists, art-going publics, theatres, galleries, public spaces, technical experts, scenographers, computer programmers, experts from various scholarly disciplines, as well as economic and/or political actors, and so on. Many of the projects that arise from these new techno-epistemic assemblages intentionally span across disciplines by engaging experiential,

scientific discovery in order to challenge the status quo of the art idea, and provoke audiences to consider new ways of interpreting, remembering and reflecting upon their art encounter. Analogously, digital media arts practitioners are drawing on intellectual and theoretical enquiries into redefined notions of (im)materiality, (tele)presence, reticulated being, networked life, cybernetics and so on, as inspiration for producing topical work. In this regard, the conceptual and practical processes of creating artworks are continually in flux; that is, they are evolving not only in relation to the individual characteristics of performance artists and art-going publics, but also in relation to the efficacy of technology, which is both exploited and instrumental in the making, reception, documentation and preservation of the work. This paper pays special attention to the cutting-edge capture technique of free-viewpoint video (FVV)⁴, which is primarily accessed using virtual reality (VR) and augmented reality (AR) headsets. This is the capture technique that we are exploring through interdisciplinary artistic-scientific practice-as-research. As a case study for this paper, we offer a reflection on a digital art project in which we reconstructed a VR version of Samuel Beckett's *Play* (1963) [2], using FVV and spatial audio techniques.

2 RELATED WORK

There is a rapidly expanding 360 video community, spanning both professional production outfits and amateur online movie-makers; however, we must stress that there is a marked difference between our VR offering and that of the *fixed point-of-view* paradigm of 360 (omnidirectional) video. There is a tendency to conflate 360 video with VR and this is erroneous. In 360 video the user does not have spatial control; they only have the ability to look around from the camera position stipulated by the movie-maker, which is not true VR. In *Virtual Play*, users have a lot of control over where they are spatially because the environment is built in a game engine and the actors, who were filmed using FVV against a green screen, are then transposed into the environment.

Combining green screen filming with 360 video has been attempted, with varying degrees of success. For example Graham Sack's *Lincoln in the Bardo* (2017) [13], adapted from George Saunders' new novel, uses the combination to portray stories about ghosts. However, they do not appear to use FVV techniques; the characters are shot using a single point-of-view camera and they apply filters to the footage in post-production to create translucency and hide the flatness of the footage. ZDF use a similar paradigm in their immersive reconstruction of a gladiator combat in the Colosseum [5], except that they capture their footage using stereoscopic techniques. Cassandra Herrman and Lauren Mucciolo's excellent, award-winning 360 documentary, *After Solitary* (2017) [3], goes one step further by combining FVV content with 360 video. However,

⁴Smolić [15] defines FVV as a video capture technique that 'offers the same functionality that is known from 3D computer graphics. The user can choose an own viewpoint and viewing direction within a visual scene, meaning interactive free navigation. In contrast to pure computer graphics applications, FVV targets real world scenes as captured by real cameras'

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¹In aesthetic and art theory circles this would be described as *naturalism*.

²We gather this term under the definition proposed by J.L. Austin, where he proposes that saying something is doing something that has real tangible and repercussive implications [1]. In the context of technology this can be understood as technology inhabiting a sort of efficacy.

³This term is deployed in the context of Bernard Stiegler's aesthetics [16], who mobilises it in the context of Gilles Deleuze [7] before him.

the users' movements are still limited to simply looking around from a fixed position—there's no attempt to simulate natural movement. Disappointingly these creative works make very little progress on VR film techniques that were already being championed several years ago by the likes of Jonathan Minard and James George in *Clouds* (2014) [11], where they harness the point cloud information of interviewees and render it for re-display in a VR environment that evokes a data visualisation. In *Virtual Play* we give the user the sense of natural movement albeit within a defined area as they are allowed to move around the space and interrogate the characters from any point of view.

Furthermore, in all of these examples we have identified some shortcomings in terms of innovation in narrative development, because they do not truly harness interactivity as a central component of progressing the story. Most contemporary offerings still tend to just use linear narrative and therefore fail to employ the full capabilities of *interactive* virtual environments. This is precisely the paradigmatic shift we intend to champion in our *Virtual Play* project, by making the user a key figure in deciding how and when the story unfolds.

3 INNOVATIVE INTERACTION DESIGN

In recent years there has been a steady migration towards generating user experiences at the crossroads of corporeality and internal computer mechanism, with video recording technologies being the favoured technique for capturing, storing, disseminating and promoting results. This has resulted in video techniques and computer-vision R&D experiencing a notable burgeoning, with AR/VR interfaces continually establishing themselves as novel and inventive viewing platforms. *Virtual Play* is a reinterpretation of Samuel Beckett's ground-breaking 1963 text, *Play*, with a view to engaging a 21st Century viewership that is increasingly accessing content via VR technologies. This project has been conceived in order to demonstrate how VR content can be produced both cheaply and expertly, and therefore challenges the notion that sophisticated VR content is exclusively the domain of wealthy institutes and production houses.

With the increasing sophistication of vision technologies there is the parallel evolution of deploying ever more advanced digital media techniques in art-making processes. These are not simply documentation techniques or artefacts to be engaged by performers, but are indeed central to the choreographic and dramaturgical development of the work. Analogously, at the viewer end, there are different criteria relating to how the work is engaged or viewed. A central goal of the project is to address ongoing concerns in the creative cultural sector regarding how to tackle the question of narrative progression in an interactive immersive environment, especially considering the type of end user that is inclined to purchase and don a VR headset. It is commonly held that by placing the viewer (audience) at the centre of the storytelling process, they are more appropriately assimilated to the virtual world and are henceforth empowered to explore, discover and decode the story, as opposed to passively watching and listening. The questions of dialogue and interaction are at the heart of this problem; it is a question of promoting the viewer to an active and efficacious role within the narrative development. This is a narrative technique that has been so successfully employed in the computer gaming industry by using procedural graphics and animation, but film and video have struggled to engage this problem effectively, in terms of audio-visual capture techniques—as discussed in the previous section. As such, this project investigates the new narrative possibilities for video capture techniques in interactive, immersive environments.

Beckett's *Play* was chosen for several reasons. As its name suggests, it specifically engages the question of *play*—invoking dialogue and interactivity—but it also responds to the formal conditions of the theatre itself (Beckett also wrote a film named *Film*). Beckett habitually uses his writing's content to seek the heart of the form



Figure 1: The character of M in the live-stream version of *Play*, workshopped and broadcast at the Samuel Beckett Centre, Dublin, Ireland, in April 2017. O'Dwyer & Johnson ©.

in which he is working, posing both a daunting challenge and an enticing invitation to anyone seeking to transfer his works across media. In the original text, the performers each have a monologue that they must recite, apparently perpetually (the final stage direction is 'Repeat play')⁵. The sequence of the performers articulation of their individual narrative is determined by the action of a moving spotlight, which Beckett calls the interrogator. Thus, *Play* is a game of interaction between the light operator and the actor, mediated by the technology. It is also a type of algorithm, in which a technological input (light on/off) creates a corresponding output (voice on/off) in a given sequence (notably, a sequence that Beckett himself opens to variation on the repeat). In the theatre, the 'end user' is a passive audience member, observing the Pavlovian trial of three actors who must speak when the light is on them and then fall silent when the light is off them; in VR, new variations on this model become possible by reconsidering the role of the user as active.

This FVV response to *Play* attempts to push the limits of possibility in consumable video and film by eliciting the new power of digital interactive technologies, as well as the specificities of the virtual reality interface, in order to respond to Samuel Beckett's deep engagement with the stage technologies of his day.

4 THE GAME CHANGER: NEW DRAMATURGICAL RULES FOR VR

Even in its home medium of the live theatre, the dramaturgy of Beckett's *Play* raises challenging questions about the nature of narrative, perception, communication, and embodiment. Though the story of the characters is a simple one of a love triangle, their situation in an apparent purgatory of endless recitation of it suggests something more malign, invoking images of torment and surveillance. The text splits between a first half that is about what happened between the three of them, spoken in first person and past tense, and then a second half that addresses the interrogator itself, with the three characters reacting slightly differently to the light (broadly speaking, M craves silence, W1 wishes not to be seen, and W2 wishes to be seen). The partnership between V-SENSE and the Trinity Centre for Beckett Studies, as well as the first collaboration with the actors⁶, occurred during a prior project entitled *Intermedial Play* (Experiment One of April 2017), in which a moving-head PTZ camera was substituted for the interrogator light, and in which the performance was broadcast live from one room to another via *WireCast*. This screened rendition highlighted the aspect of surveillance present

⁵Beckett is unclear about how many times the play should be repeated. A purely logical interpretation demands that every time we arrive at this stage direction we should repeat the play, which implies that *Play* is an infinite repetition of the dialogue. However, most performances of the text are executed twice and then finish.

⁶Please see acknowledgements for the list of actors' names.

in the text, placing the audience inside the camera as interrogator, but sought (through the pressure of a live-stream, as opposed to a postproduced product) not to discard the time-based or game-based pressure of the performance as a living system.

It is possible to imagine a spectrum of VR adaptations arising from this prior exploration of the text. The first, closest to the authorial/theatrical version but not yet utilising the power of the medium, would be to place the three urns side by side, allowing an end-user to ‘intimately’ experience the sequence that Beckett wrote, with the light as a separate and defined element of the conditions. The user could move in a defined area (near or far, left or right), but the theatrical image of three urns side by side would be maintained. Our preferred (and current) VR version goes a step further into recognising the unique characteristics of the FVV medium, by giving the power of activation over to the end user, whose gaze becomes the spotlight. End users are thus empowered to discover the interdependent monologues by themselves, merely by looking at the actors and focusing their attention on them. Whether this sequence is closed (i.e. Beckett’s defined order of the text) or open (fully randomised based on the gaze of the viewer), and if open, which rules are followed (whether the next monologue picks up from the relevant middle point, or else where it was last left by the user), becomes a question of programming and a subject of experimentation. A further range of imaginative possibilities thus opens up through the medium itself, namely what the physical ‘universe’ around the urns can look like, and whether things become possible in the digital space – such as very small urns that would be geometrically impossible in real space, or infinite fields of urns – that point our imagination of the world of the text in wholly new directions.

In order to facilitate these exciting possibilities, extensive planning and a high degree of precision from the actors during the capture phase is essential, because of the difficulty in editing and post-producing footage captured using the free viewpoint setup. Again, the actors must perform flawlessly under the pressure of the live, because there are multiple cameras simultaneously capturing the same scene from different views; the task of having to edit footage from many different capture devices is extremely labour intensive (though not impossible). Furthermore, the nature of the audience experience in immersive virtual environments insists that any edits or cuts would appear incongruent and therefore only serve to disintegrate the suspension of disbelief; glitches may destroy the continuity of the alternate reality. Since the viewing rules are completely different, it is not possible to edit a dialogue along the lines of classic cinema techniques. In VR the viewer is at once the camera and the editor, so the actors must execute any passage of text from start to finish, generating a consistent source that enables the user’s later freedom to choose where to join in. There is no ‘master shot’ that gives the opportunity to plaster over any cracks. This project, and Beckett’s play specifically, thus provide an opportunity to investigate the VR actor, and how the rules of engagement might be more like theatre than like film.

5 SCENOGRAPHY: BACKGROUND AND CONCEPT

In terms of the *mise-en-scène*, the aim is to construct a 3D re-interpretation of Beckett’s scene and characters, whom he describes as ‘lost to age and aspect’ [2], using FVV techniques. In the original script there are three characters, each encased in ‘three identical grey urns... about 1 yard high’ [2]. These are situated in a row at the front centre of the stage, and the three actors ‘face undeviatingly front throughout the play’ [2], see Fig. 2.

Beckett was notably particular about maintenance of his stage directions (though they sometimes contain contradictions) and the integrity of his texts (though they sometimes differ across published versions). When working with Beckett in an intermedial manner, a tension opens between the exigencies of the new medium and the desire to accurately and sensitively represent Beckett’s imag-



Figure 2: Scenographic layout of actors in urns, according to Beckett’s original text. O’Dwyer & Johnson ©.



Figure 3: Scenographic vision for positions of three urns in relation to each other and the user in the FVV experiment.

inative world. This dynamic resembles the ‘spectrum of fidelity’ previously theorised in relation to directing Beckett [9], where the new work inhabits a continuum between ‘authorial’ and ‘audience’ fidelity, justifying certain adaptations for the sake of accessibility to a contemporary or culturally specific audience. Regarding the new technology of reception represented by VR, one could extend the spectrum to examine the demands of the medium itself: if *Play* is going to move from the original medium to FVV, then certain scenographic or conceptual adjustments may be required for it even to function for the audience.

Beckett was a profound interrogator of the peculiarities of new media, which were, in his time, analogue. It is important that the theoretical sophistication of the work continues to challenge contemporary audiences, every bit as much as the dramaturgy and scenography remain consistent with the author’s vision. As such, we have devised a scenario in which the user (audience member) is placed in the centre of a virtual stage, which is now surrounded by the three urns on three sides. Contrary to the original script, the urns are spaced further apart than Beckett initially devised; however, we feel this is justified by the need for the user to experience a natural (and measurable) sensation of movement whilst exploring the three monologues (see Fig. 3). That is to say, a certain degree of freedom is afforded by the ability to move within and around the virtual environment, and the experience is one of *immersion* in the situation (as opposed to an *observation* of a situation controlled by an unseen other).

Scenographic and design decisions are also radically altered by the virtual space. The urns are funerary in character, and Beckett was specific in his notes that the urns should be one yard high. This means that in a theatre, the live actors either have to be 1) extremely short, 2) standing with their feet inside a trap door or other structure, or 3) kneeling with concealed legs emerging from the back



Figure 4: FVV capture setup used for capturing the actors. Seven cameras are placed covering around 150°.

of the urn. The alternative of a sitting actor is rejected by Beckett because, as he says, it would result in using urns of ‘unacceptable bulk.’ Working in VR leads to different affordances and different constraints: for example, it becomes necessary to construct the urns out of materials that are neither too reflective nor too uniform for the visual calibration process to occur, while ergonomically impossible urns can later be added as part of a digital landscape, or visible legs can be digitally amputated. An actor’s head can more easily appear as if disembodied, floating marginally above the lip (an effect that the spotlight in the theatre sometimes produces) (see again Fig. 1). In another example of alterations arising from the medium, the faces that are suggested by Beckett to be lost to age and aspect so as to seem almost part of the urns have often been interpreted in theatre and film versions as being caked in dirt or mud. The cleanliness of the actors’ faces here reflect a directorial decision to re-think what it means in digital culture to be ‘lost’ in that way: if this is a digital purgatory, rather than a literal post-burial encounter, would it not be the curated, youthful, pure faces reflecting idealised and performed memories, not unlike the Facebook pages of the dead?

6 TECHNICAL OVERVIEW

6.1 Free-viewpoint Video

The actors are shot and recorded against a green screen, using a multiple camera setup, involving seven DSLR cameras, shooting in HD video. The cameras are strategically placed, in an arc of about 150 degrees, in a compromise between scene coverage and image overlap, because both are needed for a correct 3D reconstruction of the actors (see Fig. 4).

As the system operates on the basis of constructing a 3D model for each frame of the video sequence, all input videos need to be synchronised so that each frame of the actor’s movement is concurrent in each point of view. They must also, obviously, be synchronised with the audio files, which were captured separately (as explained in Section 6.2). This is a crucial part of the workflow because the audio also has to be synched to each of the videos when everything is reassembled in the game engine, so all videos and audio must have exactly the same start and end points. The figures are then segmented using chroma keying. Although modern postproduction software greatly simplifies this task, the process has to be executed for each take from each camera and, as such, it is very labour intensive. After this, the raw (uncompressed) video footage is exported, as a series of images (one image per frame, at a 30 fps rate), along with a segmentation mask for each frame (see Fig. 5). Lastly, the camera setup is calibrated.

Our 3D geometry reconstruction system consists of the fusion of two different kinds of data: a 3D volume, estimated using shape-from-silhouette (SfS) [10] that makes use of the segmented foreground masks; and an accurate 3D point cloud obtained through multi-view stereo (MVS) [14]. This data is merged together using a 3D fusion technique, which results in 3D models that are volumetri-



Figure 5: Split screen showing a frame of uncompressed video with its corresponding mask.



Figure 6: From top to bottom: reconstructed 3D mesh, before texturing; textured model with mesh wireframe; and final photorealistic model.

cally complete, but also accurate. The resulting model is coloured through a multi-view texturing technique that uses all the input images to generate a seamless photorealistic textured model [12]. Fig. 6 shows an example of a resulting untextured model (top), the textured model with the mesh wireframe overlaid (middle), and the final photorealistic 3D model (bottom).

6.2 Spatial Audio: 6DoF (6 degrees of freedom) Audio

In order to help embellish the immersive nature of the scene we made a decision, early in the project planning, to incorporate 6 DoF spatial audio with a view to implementing binaural playback over headphones. The choice and placement of microphones for audio capture for FVV is an important consideration, as removing any visible microphones or cabling in post-production is a time consuming task. Here, the positioning of actors within the urn was quite beneficial in this regard, as this allowed for the discreet placement of a Schoeps CCM4 cardioid microphone on the underside of the rim of the urn, as shown in Fig. 7. Once synchronized with the video footage, these monophonic recordings of dialogue are then imported as separate assets into the game engine for spatialization within the Virtual Acoustic Environment (VAE). Ambisonics has become the default format for spatial audio in VR and is supported by a number of SDKs from Google, Facebook, Oculus, among others. While this technique readily supports the dynamic positioning of audio sources at different azimuth and elevation angles, the control of source distance is significantly more complex. This is particularly true in the case of FVV where the user can freely move around within the virtual environment and thus dynamically alter the distance to the audio sources, such as the three actors here. For this production, the Google VR SDK for Unity was used to implement 6 DoF within the VAE. The GVR Audio Room script included in this SDK supports the creation of a virtual acoustic room which is here configured to match the dimensions and materials chosen for the visual environment. The audio for each actor was implemented using the default GVR Audio Source script which supports 6 DoF audio in multiple ways, such as adjustments to the source directivity pattern, and dynamic changes in distance. The latter is particularly important for 6 DoF content to ensure that both the timbre, and ratio of direct and reverberant audio signals changes naturally as the user moves closer or further away from each actor. However, as maintaining a high degree of clarity in the dialogue is highly important, the overall level of reverberation was also reduced somewhat.

One of the challenges in a 6 DoF production such as this is the potential variability in the dimensions of the reproduction area. Here, the audio is designed for a reproduction area of approx. 3m x 3m with the actors positioned just outside this region. The extent of the roll off in volume as the user moves away from each source was adjusted for this reproduction area so as to ensure a clear sense of change in the perceived auditory distance as the user changes position, while still at all times ensuring sufficient overall clarity in the dialogue.

6.3 Unity Application

The interactive VR application was built using Unity game engine. The reconstructed textured models (one for every frame for each actor) with the synchronized audio files were imported into the engine and defined as Asset Bundles. In the environment, we created three nodes on a 180 degree arc representing the positions of each actor (see Fig. 8). Each node contains one component for playing the audio file (GvrAudio) and a custom script that dynamically loads a mesh for each current frame at run-time. The dynamic loading of frames (meshes) was necessary due to the fact that Unity normally attempts to load all the data into memory at the start, when all assets are placed into the scene. In this case it was overloading the GPU, because there is a discrete textured model for each frame of each character, the sum total of which is nearly 20,000 frames for the



Figure 7: Microphone Placement for Dialogue Audio Capture.

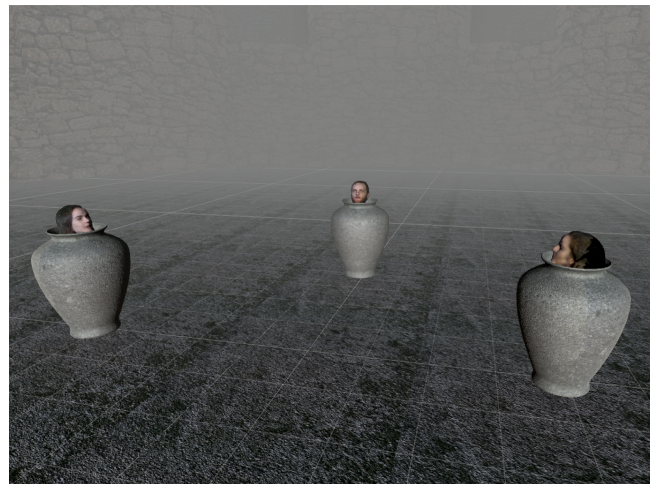


Figure 8: A screen shot from the *Virtual Play* VR application built in Unity.

entire duration of the performance.

In the theater version of the Play, the light operator controls which actor speaks, and when, by pointing a light at the one of them. In our VR application we implemented this experience by attaching a spot light to the main camera. This allows the user to direct the play by using his/her head, that is by looking at the characters. These rules and conditions that define the user interaction, behaviour and experience are all programmed into the Unity game engine.

7 AESTHETICS: TECHNICITY AND PERFORMANCE ART

This project draws upon the specific cultural artefact of Beckett's *Play* in order to reflect upon the fluctuating nature of the technical milieu, and the evolving degree to which digital media impact on the production of the performing arts. Creative artists are always looking for new, innovative ways to express themselves that are appropriate to the hyperindustrial, global economy. As such, they are increasingly incorporating *fundamentally* new techniques – which rely on technologies that are only available now in the digital epoch to explore knowledge and push the boundaries of cultural praxis and reception. The integration of these new techniques during the process of making work occasions new ways of thinking about: the (dis)embodied self; the geospatial and temporal locations of

encounter; how the performance manifests; relations between the artist, the artwork and audience; and so on. At the confluence of these techniques and themes is the performative assemblage (see footnotes 2 and 3), which is a mutable process, concerning the convergence of a number of human and non-human (technological) subjective forces. These hybrid creations represent the contemporary status of the (digital) avant-garde, because they challenge the status quo, push the limits of knowledge, dissolve traditional boundaries of practice, and elude definite classification⁷. They are experimental assemblages, often encompassing visualisation, sonification, dance, theatre, and so on. As such, they ‘disturb boundaries of traditional performance and create new paradigms of emergent practice and discourse’ [4]. This mirrors the evolving reception of established cultural artefacts within digital culture and aesthetics, in which the living legacy of Samuel Beckett, for example, is one that transgressed and rewrote numerous aesthetic boundaries in its original context, and as such, it insistently demands re-engagement. Such projects have arguably contributed to impelling a shift away from the scopic regime of the performance spectacle, toward a more theoretical, process-driven, phenomenological and experiential methodology. Within this performance paradigm, there is an emphasis on highlighting the post-Heideggerian, expanded understanding of technology as something not at all dualistically opposed to the human; conversely, it is understood as a mutating phylogenetic⁸ meta-phenotype⁹ that continually redefines how humans think about themselves, their interactors – individual and collective – and the ideologies to which we subscribe.

8 CONCLUSION: USER FEEDBACK AND QUALITY OF EXPERIENCE ASSESSMENT FOR VR/AR CONTENT CREATION

Studying saliency for omnidirectional images in VR is an important research topic. Recently, researchers have conducted numerous subjective experiments to collect viewport centre trajectories (VCTs) and have engineered a method to transform the gathered data into saliency heat maps [6]. It is held that this data can open important insights into issues around human attention, and it can facilitate a better understanding of human viewing behaviour. Such data is central to important logistical concerns concerning the transmission of the large amounts of data over electronic networks, and ultimately may help to establish VR as a viable consumable medium, in a consumer market where it must compete against entertainment incumbents such as on-demand television, film websites and multi-player online games. Gathering quantitative user data – relating to their position, what they are looking at, and for how long – will be an integral part of the application. We will use this information to generate new, innovative types of saliency maps that integrate data from the six degrees of user movement as well as the already established paradigm of viewport centre trajectory. The goal is to collect the data so that it can be analysed, written about, published and made available as an open dataset. Ultimately, the objective is to help improve the quality of user experiences, not just in our own productions, but also in all VR productions world-wide, thereby helping to solidify VR as a quality medium for experiencing art, stories and narratives in innovative and pleasurable ways.

All fields of knowledge, without exception, and all aspects of social organisation, are reinvented by developments in the technical systems that constitute culture. With the emergence of the digital, this reinvention is traumatic every bit as much as it is beneficial. For

example, while domestic hardware maintains the power to run sophisticated software tools, which enable amateurs to create content that was traditionally only within the ambit of expensive production houses, there is also the reality that these same software tools are automating tasks and ultimately bringing about the obsolescence of skills, jobs and knowledge. Without trying to oversimplify the discussion into the polemics of the Luddites and the technophiles, the point that surely must be pressed at the conclusion of this paper is the need for more interdisciplinary dialogue, because it is through the recombination of particular intersections of technical and social knowledge that new possibilities are discovered and new specialisations are invented. Varying degrees of techno-social efficacy can ultimately affect and shape individuals and collectives in ways that enhance, reinvent and supplement human experience, and sometimes even completely overturn preconceptions of meaning and what it means to be human.

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⁷Of particular pertinence to this argument is Steve Dixon’s important volume, entitled *Digital Performance* [8], which teases out the inherent avant-garde and experimental qualities of digital media performance

⁸Phylogenesis is the evolutionary development and diversification of a species or group of organisms, or of a particular feature of an organism.

⁹A phenotype is the set of observable characteristics of an individual resulting from the interaction of its genotype with the environment.