

Countering the “Digital Uncanny:” Post-Processing for 3-D Digital Heritage

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Photogrammetry and laser scanning, or combinations of the two, are increasingly used in cultural heritage settings to create three-dimensional digital replicas. Yet the technical production processes involved can sometimes result in undesirable outcomes – flattening shadows, light, and surface textural variations of original artifacts. Many of these important visual cues contribute to our understanding of digital models as ‘historical objects,’ and the resulting overly digitized photogrammetry – lacking visual context and depth – can impede user interactivity. Viewers of digital heritage can become deterred by the uncanny, static, or unreal aesthetic of some photogrammetric and laser scans. This article considers two digital heritage projects: “Emotions3D: Bringing Digital Heritage to Life,” and the Smithsonian Apollo 11 Command Module scans in order to explore how technical and curatorial decisions can address issues in photogrammetric and laser post-processing. While often subtle, different post-processing choices are perceived and deeply cognitively and emotionally internalized by viewers and users of digital cultural heritage. Therefore, this paper assesses the relevance of emotions studies, theories of the ‘uncanny’ and the ‘uncanny valley,’ and issues of authenticity and best-practice digital interventions to enhance user engagement and accessibility through digital post-processing techniques.

Key words:

Photogrammetry, “Uncanny Valley”, Digital Curation, Post-Processing, User-Engagement, Emotional Interactivity.

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1. INTRODUCTION

Photogrammetry, or structure-from-motion modelling, produces textured, photorealistic replicas of original objects. These digital replicas have many applied functions for conservation, research, education and public outreach in museums; yet due to the production process of creating a 3-D model by aligning 2-D photographs in digital space, these models are often not an exact likeness of real objects. Instead, photogrammetric models are better conceptualized as collages, or photographic 3-D composites. Side-effects of the photogrammetry production process can result in photogrammetric ‘flattening,’ where realistic lighting and shadow, signs of aging and wear, and lifelike surface texturing – factors which normally contribute to a convincing picture of historicity – are conspicuously absent. As such, digital heritage artifacts created from photogrammetry can

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sometimes produce effects akin to the concept of ‘the uncanny’ – a sense of perceptive uncertainty, emotional detachment, or cognitive discomfort.

Overcoming these factors should be a priority for cultural heritage institutions seeking to improve user engagement with digital artifacts. This article outlines some of the ways interpretive photogrammetry post-processing can ‘reinsert’ visual markers which consciously and subconsciously alert viewers to the cultural heritage status of digital objects. There are many challenges to doing so, including existing technological capacity, the curatorial understanding and interpretation of digital authenticity, and conceptualizing the effects of uncanniness in non-humanoid digital objects. Using case studies from the Smithsonian Institute’s photogrammetric model of the Apollo 11 command module and an Australian Research Council Centre of Excellence for the History of Emotions digital heritage project, Emotions3D, this article explores several theories of the uncanny, as well as technical curation for photogrammetry, and finally the pursuit and creation of ‘realism’ to improve emotional engagement in digital museum settings.

The present discussion is guided by emerging scholarship from both emotions’ studies in digital contexts and the history of emotions in cultural heritage. The relevance of emotions to 3-D processing and the ‘uncanny valley’ ultimately stems from the theoretical basis that user engagement with digital heritage has both emotive and cognitive functions. These functions can be influenced by technical alterations to 3-D digital objects as part of curatorial preparation using post-processing. Essentially, this article explores how we might do so and why we would want to. While the digital models in the two case studies are displayed in online environments, the focus of this article is on their display within a general digital context, which could be based on either individual websites accessed from personal computers or an interactive digital display in a museum. This article focuses exclusively on smaller-scale heritage objects, but may also be expanded to larger-scale immersive environments. To demonstrate the effects of the uncanny valley and the alteration of emotional states in response to cultural heritage, the two cases studies of recent 3-D digital projects explore notions of likeness, familiarity and authenticity in the cultural heritage context. Ultimately, this article posits that theories of the uncanny and an emotions-based approach collectively support digital realism and interactivity, resulting in a suite of best practice parameters which can be used to create and shape digital cultural heritage.

2. ‘UNHEIMLICH’ AND ‘BUKIMI NO TANI’ IN DIGITAL CULTURAL HERITAGE

Theories of ‘the uncanny’ and the ‘uncanny valley’ provide a compelling ontological platform for understanding how user engagement with cultural heritage photogrammetry may become inhibited in digital environments. The original concept of the ‘uncanny valley,’ a theory popularised by Japanese robotics engineer, Masahiro Mori, outlines the sense of detachment and alienation when interacting with robots on a spectrum of human likeness. In his 1970 essay “Bukimi no tani (The uncanny valley),” Mori suggested that “when humanoid forms appear ‘too’ real, (yet are perceivably unreal), our capacity for empathy or acceptance drops dramatically” [Krischer 2011, 129; Mori 1970].

Sigmund Freud had somewhat foreshadowed this idea of ‘acceptance’ versus ‘the uncanny’ as opposing ideas on the same spectrum in his famous 1919 paper, ‘Das Unheimliche’ (The Uncanny) [Freud 1919]. The Freudian concept of unsettling unfamiliarity is outlined thus: “*Heimlich*

[homeliness] is a word the meaning of which develops towards an ambivalence, until it finally coincides with its opposite, *unheimlich*. *Unheimlich* is in some way or other a sub-species of *heimlich*" [Freud 1919, 4]. For Freud, building on Joseph von Schelling and Ernst Jenstch's ideas on the uncanny, "'The uncanny' is nothing new or foreign, but something familiar and old – established in a mind that has been estranged only by the process of repression" [Freud 1919, 13]. Freud outlines several forms of *unheimlich*, deriving from severed body parts, the return of the dead, wax-work figures, dolls and automata, the concept of doppelgänger or double, epilepsy and madness, and several others, all of which amount, according to Freud, to repressed psychological complexities brought to light in an untimely or inappropriate fashion [Freud 1919, 14, 17, 19].

Freud's overarching idea of 'the uncanny' is seen as a natural progression of the phenomenon away from its original counterpart *heimlich*. Building on this idea, Mori suggests that *heimlich* increases over time, before experiencing a rapid decline into *unheimlich* before peaking at the highest likeness to reality, such as with a healthy human subject. Mori illustrated his theory of the 'uncanny valley' as a line graph, where the 'uncanny valley' occurs as a dip in an upward curve of likeness and familiarity. This trough occurs right before full acceptance, suggesting that *almost* lifelike digital subjects are most likely to engender cognitive discomfort or even revulsion. In research into the effects of the 'uncanny valley,' the emotional interplay with humanoid or human-like objects can be quantified against predictable relational markers. In other words, we can fairly accurately determine the point where a human-like figure becomes unsettling [Geller 2008].

The idea of the 'uncanny valley' has hitherto only been applied to humanlike subjects, yet photogrammetric objects in heritage, as opposed to Computer Graphics Imaging (CGI) virtual reconstruction of heritage, may also be particularly susceptible to the pitfalls of the uncanny valley. The photorealistic textures of photogrammetry models mean that photogrammetry is fundamentally close to lifelikeness, so the possibilities for uncanniness are heightened when compared with other forms of digitisation. If, as according to Misselhorn, 'more realistic faces trigger more demanding expectations for anthropomorphic depictions' [Misselhorn 2016, 349], then it stands to reason that more realistic *non-human* objects also trigger similarly demanding expectations for realism and authenticity. When these representations fall short, viewers are potentially repelled. It is therefore possible for non-human objects (such as cultural heritage artifacts), to be subject to the same uncanny effects.

According to Mori's theory, uncertainty in perceptual cues arise from uncanny stimuli when individuals perceive conflicting category membership – such as when a viewer sees a photorealistic digital replica of a heritage artefact which is no longer being judged by the standards of a replicant, but as a defective version of the original artifact. Photogrammetric modelling often removes traces of realistic lighting, signs of aging and wear, and lifelike surface texturing from the replica of the original artifact – eroding the capacity for digital objects to adequately convey cultural status and context. In a photogrammetric replica, viewers may only subconsciously be aware that these aesthetic markers are absent, but can nonetheless experience difficulty in forming attachment to digital heritage replicas simply because the object is almost, *but not quite*, completely lifelike.

Freud also outlines the uncanny effect of epileptic seizure and the manifestations of insanity, explaining that spectators experience the feeling that "automatic, mechanical processes are at work,

concealed beneath the ordinary appearance of animation” [Freud 1919, 5]. Visual and aesthetic cues produced during the photogrammetry process might also elicit the same sensory reaction in viewers. Such digital replicas convey a sense, however understated, of the underlying mechanical or technical process of production (even with very old, or deeply communal or personal artifacts), which may unsettle viewers and lead to their cognitive disconnection from the object. Likewise, Freud develops Otto Rank’s idea of ‘the doppelgänger,’ or ‘double,’ which closely parallels the potential for detachment from digital replication [Freud 1919, 9]. Here, the very notion of producing digital copies of unique cultural heritage artifacts may induce feelings of uncanniness. These digital doppelgängers also blur the distinction between imagination and reality, according to Freud, “such as when something that we have hitherto regarded as imaginary appears before us in reality, or when a symbol takes over the full functions and significance of the thing it symbolizes” [Freud 1919, 15]. A better exemplar for the creation of digital heritage cannot be articulated. Viewers of digital cultural heritage are presented with a replica, which, because of the emerging digital agenda and potential for mass distribution, may subvert the primacy of the original object and may therefore lead to emotional and cognitive detachment.

The concept of ‘cue realism,’ by which particular visual and aesthetic conditions create a sense of realism (or not), is subject to processes of cultural habituation and also subject to changes over time [Brenton et al. 2005, 2]. Perhaps, in time, our “perceptual systems will be retuned” [Saygin et al. 2011, 8], and growing familiarity with 3-D digital replication and its potentially altered aesthetic will become accepted as a new norm in cultural heritage. Until this takes place, however, some aspects of unprocessed digital heritage may continue to unsettle and deter viewers. Theories of the uncanny provide a rare opportunity to better understand the sense of alienation and detachment occasionally experienced with digital cultural heritage visualizations. The uncanny provides an exemplary tool for understanding and address issues with cognitive strangeness or unfamiliarity in digital replicas, which are sometimes not executed in accordance with viewer expectations. The use of the ‘uncanny valley’ as an uncritical thought experiment has been challenged and further refined since the 1970s [Brenton et al. 2005, 1-2], and is developing into an established discipline within the robotics, human-computer relations, psychology, gaming and 3-D animation industries [Lay et al. 2016, 2]. Yet, despite increasing complexity and neuroscientific applications, uncanniness remains consistently present in many interactions with digital CGI subjects and non-human objects, which may also extend to digital cultural heritage subjects.

3. THE DIGITAL UNCANNY IN HERITAGE: AN EMOTIONS-BASED APPROACH

The role and history of emotions are increasingly relevant within the field of critical heritage studies, and can also significantly inform this discussion of the uncanny valley in digital heritage. Laura Jane Smith [2006], Gaynor Bagnall [2003], Michael Haldrup and Jørgen Ole Bærenholdt [2015] explore the concept of ‘heritage’ as a series of emoted, embodied, or performed interactive processes, where (according to museum studies scholar Louise Ravelli), “there is an important relationship between *affect* (feelings, attitudes and emotions) [...] and the overall interactional meaning in an exhibition” [Ravelli 2007, 133]. The interplay between cognition, emotions and materiality (digital or otherwise) is a principle focus of this article, with the growing primacy of ‘engagement’ in the museum and heritage environment further foregrounding the role of emotions. After all, engagement may largely

be conceptualized as the emotional and cognitive responsiveness to exhibits or artifacts – the recursive and fluid interactions between the user and the object. Emotional appeal, the shaping of mood, and the enhancement of visitor comfort, familiarity, and interaction (while overcoming uncanny cognitive revulsion) is also an integral part of the conversation around heritage in digital environments [Stenglin 2004; Pang 2004]. Thus digital environments provide ample capacity to better evaluate and attune viewer interactivity and overcome emotional reactions to uncanniness through artificial or technical means.

Emotions-based approaches to digital heritage, and the overlapping fields of neuroscience and linguistic definition, provide a larger framework for understanding the specific idea of the ‘digital uncanny.’ Catrin Misselhorn’s scholarship on Mori’s theories of the uncanny valley probes the role of emotions and emotional responses at all levels: first from a phenomenological approach (reflecting on the uncanny perceptual process from a first-person perspective); then from an empirical approach – based on quantitative research in psychology and the neurosciences; and finally from a philosophical perspective which provides the conceptual tools to bridge the first two perspectives [Misselhorn 2009]. Evaluating human-robot interactions, Misselhorn explores feelings of eeriness and empathy in great detail and attempts to explain the abstracted cognitive and emotional mechanisms responsible for the emergence of the uncanny valley [Misselhorn 2009, 350]. While Misselhorn focuses on interactions with human-like robots, her development of the precise processes of perceptual experience and the operation of the uncanny at a subconscious level contribute significantly to the conversation around engagement with digital cultural heritage objects.

A 2011 collaborative study, led by the Department of Cognitive Science and Neurosciences Program, University of California, used functional magnetic resonance imaging (fMRI) to map neurocognitive processes of humans perceiving human, robot and humanoid movement and appearances. The controlled fMRI imaging for the android stimulus produced distinctive and increased patterns of brain activity, which differed significantly from both the human and robot conditions [Saygin et al. 2011, 6]. The study concluded that the interplay between predicted appearance and realized appearance violated perceptual expectations in human test subjects with striking effect [Saygin et al. 2011, 7]. Heightened brain activity can be explained by a disjuncture in perceiving and predicting motion and appearance in uncanny, robot/human hybrids. The uncanny valley can therefore be understood from a preliminary neuroscientific perspective, directly modelled by our cognitive and emotional processes using experimental techniques within a controlled laboratory environment.

Other studies which investigate the use of emotional language in relation to the uncanny valley can also inform the principles of uncanniness in digital heritage [Misselhorn 2009]. A 2008 study investigated the differences in a range of ‘emotion words’ used to describe eighteen video clips of robots and a woman [Ho et al. 2008]. This study concluded that different emotion words correlated to different aspects of human likeness or unlikeness, mapped relatively closely to representations of uncanniness on the realism/interactivity spectrum. The study also determined how closely emotion words are correlated with the attributes of ‘eerie,’ ‘creepy,’ and ‘strange’ [Ho et al. 2008, 170]. This study conjectured that words used to describe the robots also had different emotional registers and valences – linguistically, ‘strange’ was considered to describe a more cognitive or detached response, while ‘eerie’ and ‘creepy’ were understood as more perceptual and emotional. According to this

research, the term ‘fear’ is highly predictive of attributions of eerie or creepy, and disgust, shock, and nervousness are also significant predictors [Ho et al. 2008, 175]. The nexus of indicators for the uncanny in this study supports the idea that revulsion and cognitive discomfort towards non-human digital renderings may be part of this phenomenon and should be considered in further research in this area.

Additional linguistic and ontological similarities when comparing human-humanoid interactions and human-digital artifact interactions include a focus on ‘disgust’ combined with ‘unpredictability.’ Like the ‘heimlich/unheimlich’ spectrum, these emotional expressions of the uncanny are both conceptualized emotionally as opposites, or absences, of desire (or at least tolerance) and predictability [Ngai 2005, 332-37]. Hence, there may be an element of negative surprise to the digital uncanny. Conversely, the fear of death which characterizes early conceptualization of the uncanny may not be quite so problematic in the digital heritage context – historical objects are supposed to carry signs of decay, deterioration or wear. This makes them *more* ‘authentic,’ and, as we will see below, may be used as a tool to increase positive user engagement. A fruitful avenue for further research might explore whether user engagement with digital heritage objects replicates other established features of the uncanny, such as an absence of essential human-ness, described in some studies as the ‘soul’ or ‘spirit’ – perhaps developing the theoretical origins of Benjamin’s ‘aura’ in relation to material objects. Likewise, a randomized controlled trial which examines the tangible experiences of those engaging with 3-D photogrammetry in a cultural heritage context would yield necessary empirical evidence for this phenomenon in relation to digital objects.

4. RE-LAUNCHING THE APOLLO COMMAND MODULE: A CURATORIAL CASE STUDY AT THE SMITHSONIAN

To mark the 47th anniversary of the moon landing, the digitization program of the Smithsonian Institution undertook a large-scale digital heritage project featuring the Apollo 11 landing module. The intricate interior and exterior of the craft, held in the collection of the Smithsonian National Air and Space Museum, were modelled using laser and photogrammetry technology to produce high-resolution 3-D models. A selection of these models can be viewed online, and many parts are also available for download – which can then be 3-D printed, viewed in virtual reality (with a lower resolution render), and read as raw data files. The open-source, online distribution of the models means that they are accessible to viewers with internet access across the globe. This offers viewers an unprecedented opportunity to view the module, especially considering that the interior of the craft is not currently open to the public, and the “protective covering over the hatch opening of the Command Module has only been removed a handful of times since the artifact came into the collection in 1971” [Smithsonian Institute 2016]. According to an accompanying press release, “The 3-D model will also be featured in the upcoming exhibition “Destination Moon,” slated for opening at the National Air and Space Museum in 2020” [Smithsonian Newsdesk 2016]. Such reasons for digitization are frequently cited by museums around the world; increasing public access and awareness are some of the biggest drivers of cultural heritage digitization.

The Smithsonian Digitization Project, led by the Digitization Project Office, the Chief Information Officer, and various working groups within the organization since 2010, is a world leader in best-

practice cultural heritage digitization policy and procedures as well as digital delivery methods for 3-D data in research, education, and conservation [Smithsonian Newsdesk 2016]. It is noteworthy, then, that the description accompanying the raw data files of the landing module explicitly states that “We strive to make ‘least interpreted’ data available for download so that students and scholars alike can understand how we arrived at our final visualizations” [Smithsonian Institute 2016].

The highly deliberate curatorial decision to release digital models with a minimal application of post-processing techniques ultimately removed shadows and textural depth when compared with digitally modelled artefacts in other heritage settings. The absence of post-processing applications on the Apollo 11 landing module has therefore resulted in models that, in some ways, appear ‘flat’ and lifeless, with no visible signs of age. The experience of the Apollo command module becomes ‘eerie,’ almost as if the true-to-life photogrammetry was produced using CGI. The sense of ‘unrealness’ in the Apollo 11 models is reminiscent of sensing the uncanny, and like the inevitable danger near Masahiro Mori’s approach to full lifelikeness, the Apollo landing module project seems to have become lodged in the uncanny valley.

Contextually, there are reasons for this result. The intricate nature of fixtures and fittings within the lander, combined with the prevalence of reflective surfaces on both the inside and outside of the craft, meant that creating convincing models was extremely technically difficult [Smithsonian Institute 2016]. Custom 3-D scanning equipment, software, and original algorithms for integrating massive composite datasets were developed specifically for this project. The curatorial team also employed seven different scanning technologies to create “one of the most sophisticated scans ever made of a historic artifact” [Smithsonian Newsdesk 2016]. The decision to forego further post-processing possibly reflects these challenges. The lack of realism or lifelikeness may also relate to the subject matter of the model. The Apollo command module is a relatively modern, technological object built during the latter half of the twentieth century in an era fixated on visually futuristic design. Yet the model, despite the original artefact being nearly fifty years old, does not convey any sense of age whatsoever. Users have commented that the model looks like a CGI interior in a modern computer game, highlighting the inherent differences between CGI and photogrammetric imaging, and showing the limitations in the former to articulate a refined cultural heritage aesthetic.

The composite model files are also accompanied by a description which states that “perhaps you will come up with your own use of these datasets,” and upon downloading, the viewer is told “we’d love to know how you’re using the files and what kind of work you do” [Smithsonian Institute 2016]. This implies that the museum intended for users to undertake their own post-processing of the models and was clearly trying to foster an interactive element to their display and use.

A principle tenet of democratized digital heritage is the involvement of users in heritage design and interpretation [Taylor and Gibson 2016]. When coupled with Richard Bayliss’s assertion that 3-D digital replicas and their associated methodologies should serve as heuristic tools rather than uncritical visualization media [Bayliss 2003, 288-89], the best-practice deployment of 3D heritage should be educative, iterative, and experiential. By making unprocessed models available to users, the Smithsonian encouraged generative co-creation of digital heritage datasets. This process develops the technical skills of users, and creates assets which can be employed in a range of open settings in accordance with user choice. In purposely providing ‘raw’ files, without additional post-

processing renders for users to manipulate, the Smithsonian curators promoted the dissemination of raw data over a favourable cultural aesthetic. However, in this situation, an approachable cultural heritage aesthetic may arguably be more important to encouraging user interactivity than providing ‘clean’ data. To many users without developed technical skills, the Apollo 11 models may remain inaccessible and unsettling, providing an exemplar for how the approach to photorealism is fraught with the potential to deter viewers.

5. CLIMBING OUT OF THE VALLEY AND TOWARDS USER INTERACTIVITY: POST-PROCESSING EMOTIONS3D

A 2016 cultural heritage project, Emotions3D, used post-processing interpretation to enhance user engagement and address some of the issues experienced with the uncanny in digital heritage. The project, based at the Australian Research Council Centre of Excellence for the History of Emotions (Europe, 1100-1800), promoted the use of interpretive digital curatorial techniques (as opposed to raw three-dimensional data), to enhance affective engagement in three-dimensional, digital, and online contexts [Nancarrow 2016 (1)]. The project, ‘Emotions3D: Bringing Digital Cultural Heritage to Life,’ embedded interactive 3D models into an online digital heritage resource, accompanied by historical descriptive content. These descriptions were specifically tailored to enhance an emotional engagement with each object’s historical and material context. Pertinent parts of the descriptive content were also appended directly onto the 3-D objects. The repercussions of an emotions-based digital heritage approach have larger consequences in the wider museum context, as these techniques can be used to shape and explicate more immersive and participatory experiences with the past.

The foregrounding of emotional experience was embedded at various stages of the Emotions3D project, including the initial research design, where items in the collection were selected for their alignment with emotional valences of “fear, love, joy and sadness, as well as more complex concepts such as anticipation, empathy and nostalgia” [Nancarrow 2018, 199]. The wider Emotions3D project helped viewers to understand how objects were used to fashion identities and shape social and emotional interactions throughout history, influencing how we understand and relate to 3-D objects as contemporary three-dimensional virtual objects today [Nancarrow 2018, 199]. The content creators of the ‘emotional biographies’ appended to each object were encouraged to explore their own emotional responses to the objects as part of the research brief, and finally, users were asked at the conclusion of each artefact description to probe their own feelings towards the 3-D digital objects, given the emotionally interactive content contained within. Thus, the Emotions3D project applies the emerging discipline of emotions studies as a critical and comparative framework in a number of ways within the context of three-dimensional digital heritage.

The ‘emotions history’ and interactivity aspects of Emotions3D were also designed to regulate many aesthetic effects of the uncanny valley in relation to non-humanlike objects. Autonomous control over how users chose to view objects in three-dimensions increased the capacity for interaction and cognitive affinity (Fig. 1), and additional techniques were employed during post-processing, many of which were adopted or refined from traditional curatorial practice. Many parts of the online resource were tailored to enhance a sense of presence and realism. The Emotions3D project contributes to our

understanding of how digital cultural heritage can be curated to appear 'aged' and part of a shared, emotionally resonant past. This aligns with Mark Dorrian's research into 'affective museum atmospheres,' which posits that 'atmospheric manipulation can be used to overcome social alienation and estrangement from museum collections' [Dorrian 2014, 187]. Through strategies of immersion, and building on Walter Benjamin's ideas about aura and aesthetics, we can tailor the experience of museum objects via the wider sensory conditions in which they are situated [Dorrian 2014, 197]. In these ways, the Emotions3D project explored how curatorial interpretation can counteract the naturally occurring, but detrimental, effects of digital heritage estrangement.

Lighting plays an integral part in museum curatorial practice in institutions across the globe. Heritage objects and museum displays can be grouped, singled out for intense scrutiny, and demarcated according to moody or airy lighting conditions. Light can be used to draw the eye to objects and the interplay of light and shadow across surface textures can be used to guide viewing experiences [Karlen and Benya 2004, 56; Hunt 2009, 15-16]. In order to accentuate each of the objects, Emotions3D employed particular lighting conditions using the customizable features on the online model hosting site, Sketchfab, as part of the final post-processing stage of visualization. Emotions3D enhanced dramatic tension by creating largely darkened digital exhibition spaces using pre-programmed 'backdrops' available on the Sketchfab website. The pre-set 'Tropical Ruins' backdrop conveys a sense of historicity and dynamism which would not be present in a completely unadorned digital context (Fig. 2). Compared with the un-curated bare background of the Smithsonian Apollo 11 viewer, the customized backdrop in Emotions3D echoes current trends in museum curation which use spatial context to create a sense of appropriate cultural vitality (without detracting attention from digital objects) [Ravelli 2007, 132].

The lighting intensity and focal length of the 'Tropical Ruins' backdrop was reduced for most of the Emotions3D collection models (to avoid the background overshadowing the content), yet other lighting conditions on the actual models were adjusted and amplified to create a more engaging aesthetic. Museums often use single beams of light cutting through the darkness to illuminate particular objects and even particular features on a single three-dimensional object [Hunt 2009, 15]. Emotions3D used post-processing lighting techniques in a similarly active, calculated way to draw the attention of the viewer and shape user experience within the lit digital space. Each object in the Emotions3D collection was given a subtle vignette and narrowed depth of field to highlight that the digital models were photographic compositions, echoing the effects of tailored down-lighting in a museum context and alerting the viewer to the artistic context and properties of each object. Likewise 'bloom' was added to the digital models to create glowing highlights. This effect is akin to the use of Gobo structured lenses in conventional museum settings (which project specific images and patterns onto the surface of objects), or when sharp edged light beams are used to make 2-D objects "glow from within" [Karlen and Benya 2004]. The application of a 'grain' filter onto each object emphasised surface texture and detail – a feature that, by comparison, was almost completely absent in the untextured environment of the Apollo 11 command module digital model. Finally, technical tone mapping was used for dramatic effect; adjusting exposure, brightness, contrast, and colour saturation to alter users' perception of the heritage status of objects and reintegrate digital artifacts back into the cultural context of the museum.



Figure 1. The ‘virtual tour’ function takes viewers on a digital 3-D journey. Users can manipulate the 15th-century Stirling Burgh Box using pre-selected annotation points to peer at the stained pages of a medieval Book of Hours which line the lid and interior of the object.

The initial viewing angles of each object in the Sketchfab viewer were chosen to ‘bring the viewer’ to the most engaging initial viewing point from which to approach each object. This is similar to the way curatorial staff position objects within museum displays to maximize interaction with objects while maintaining the flow of pedestrians through museum spaces. In addition to this, viewing angles for each object were tailored further through deliberate annotation markers which tour the user around each object. Annotation points on each 3-D model provided the opportunity to rotate each object according to specific features (related to their function or material properties), and allowed the viewer unprecedented access to all of its parts. For example, viewers can appreciate how Japanese cultural artifacts, ‘Netsuke,’ were designed to amuse or delight their owners in their original historical context, by displaying delicately carved toes and expressive faces on every side of each object, including their underside (Fig. 3) [Nancarrow 2016 (2)]. Many of the viewpoints on the 3-D models in this collection were integral to understanding their full cultural context, yet would never be seen if the object was displayed in a conventional museum. It must be noted that, since the release of the original Apollo landing module models in 2016, that the Smithsonian has also added a range of models with tour functions in a separate part of the website; however, this resource could be more fully integrated in order to showcase the full range of digital 3-D experiences with the command module.

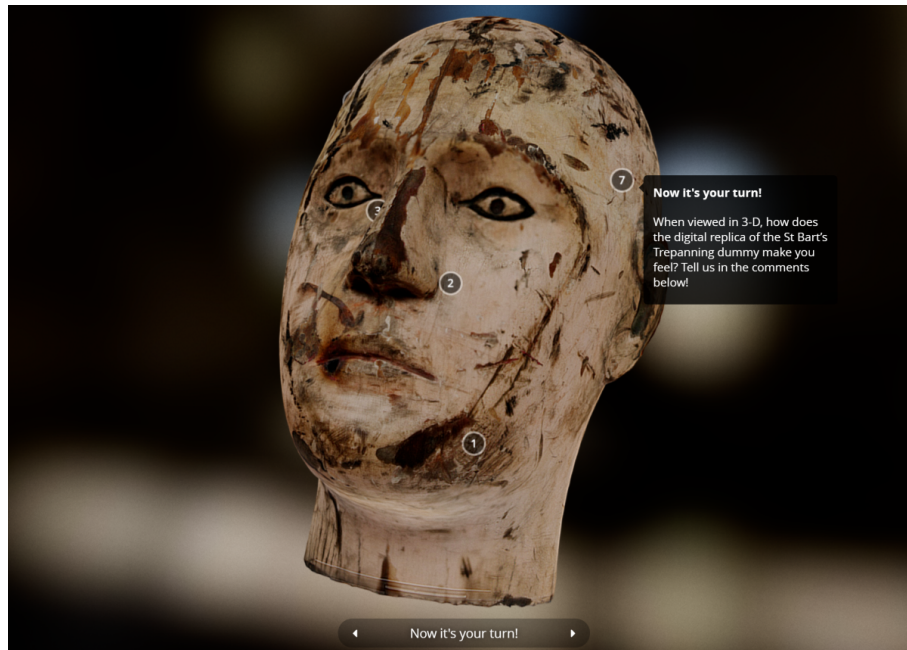


Figure 2. The lighting conditions and the backdrop for each object in the Emotions3D collection were tailored to replicate a cultural heritage aesthetic and enhance user interactivity.

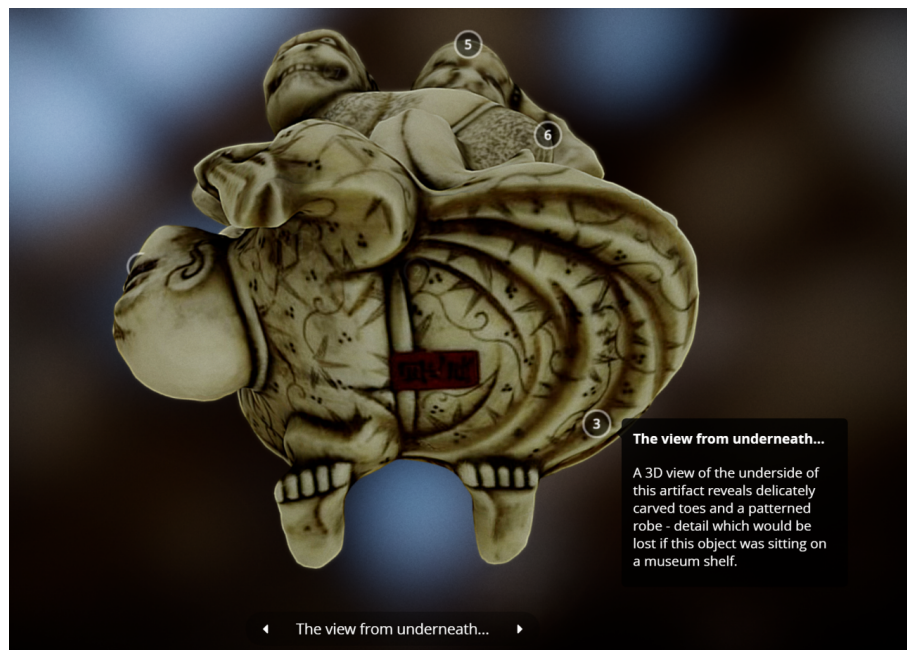


Figure 3. The delicate toes, here visible in 3-D on the underside of this Japanese Netsuke carving, might normally be hidden or unseen in conventional museums displays, but are integral to understanding this object's cultural and emotional meaning.

Museums are increasingly condensing descriptive content accompanying cultural artifacts; or removing it altogether [Kottasz 2006, 101; Bradbourne 1999]. This attempts to reduce the cultural apparatus by which museums have traditionally mediated our experiences with cultural heritage, and places possibilities for interpretation back into the hands of viewers [Kalay 2007]. Emotions3D adheres partly to this principle by separating longer descriptive content away from the visual engagement with the object. Emotions3D offers short but carefully curated descriptive content to all parts of the objects – reducing the amount of information provided with the object but offering new ways to access information directly appended to its material properties. Longer descriptions which accompany the Emotions3D collection were designed to help viewers understand the original cultural and emotional context of each object. Although each description is carefully researched, it does not display upon immediately viewing each object. This reduces ‘visual clutter,’ while allowing viewers access to a deeper emotional understanding of objects. The quarantining and control of the information which is appended to each object enhances the sense of material immediacy and cultural presence [Nancarrow 2018, 204].

Many of the post-processing features employed in the Emotions3D project demonstrate that digital heritage aesthetics can be completely tailored – sometimes beyond the capacity of natural spatial and environmental conditions. For example, customizable viewing angles can create a complete artificial approach to a museum object, as well as removing the potential for users to block light falling on objects through the application of customised digital lighting techniques. Similarly, digital heritage offers the potential to overcome conditional lighting effects such as natural light constraints within buildings, or damage done to artefacts through lighting and display. Not only do digital and virtual environments offer an increasingly similar viewing experience to seeing the original object, but they offer new ways to customize cultural heritage content – experimenting with object aesthetics and the structure of display to meet additional needs of viewers and heritage institutions. Such visual cues, as we saw above, are often appropriated from conventional curatorial practice, and can alert users to the cultural heritage context of each object. Digital modelling techniques can therefore create artificial heritage environments outside of the museum. Photogrammetry post-processing can also make digital cultural heritage appear more lifelike and emotionally engaging – affecting user perception at a subconscious, cognitive level – and can be deployed to overcome aspects of the digital uncanny.

6. REALISM, AUTHENTICITY, AND INTEGRITY IN THE DIGITAL MUSEUM

When photorealistic digital likenesses deviate too significantly from the appearance of their real-life counterparts, post-processing can ideally be used to recreate aesthetic properties and overcome uncanny photogrammetry effects. Yet reinserting visual markers that suggest a sense of age and realism do not necessarily provide a completely ‘authentic’ rendition of cultural heritage objects (as technologies are currently able to produce). While post-processing can be informed by a technical understanding of an object’s material properties, it remains, in essence, a somewhat creative process. The effects produced in the post-processing stage are interpretive, subject to the intuition and creativity of the digital designer. This raises the issue of competing priorities in contemporary museums: whether the designer is responsible for presenting digital heritage objects as realistic reproductions, or whether some degree of interpretation is required in order for viewers to more fully

engage with an object. Museums must decide whether objectivity or interpretation (and corresponding categories of authenticity or realism) are more valuable, and also determine the extent of their investment in the idea that realism increases user acceptance or affinity [Pollick 2010, 69].

Kenneth Clark, discussing the 'landscape of fact,' states 'the architect strives for naturalism, not ultra-realism. However 'naturalism' is defined, the landscape of fact aims to communicate both what a person would experience and/or observe empirically.' Here, Clarke highlights the capacity to digitally render some aspects of a scene in order to accentuate "sensory, material details" [Kingery-Page and Hahn 2012, 73]. Likewise, cinematic visual-effects supervisor Matt Aitken agrees that such stylisation is necessary in filmmaking – and helps avoid possible uncanny valley issues: 'What we're after is a digital facsimile of the human actor that's believable for that shot. That might be different from a realistic facsimile of that actor.' The capacity to digitally manipulate photogrammetry provides a unique opportunity to tailor the experiences of viewers in similar ways.

Erik Champion also argues against the primacy of authenticity and adopts a fluid approach to realism, citing engagement and atmosphere as more compelling priorities for museums. While Champion's work pertains explicitly to large-scale cultural heritage visualizations and simulations; engaging, atmospheric content can also be pursued within small-scale single-object exhibition spaces in the online environment. By comparing the Smithsonian Apollo 11 command module model with the Emotions3D project, we are also highlighting the competing individual preferences of different institutions in relation to this issue. The Apollo 11 module offered users the capacity to interact with the digital model and undertake post-processing themselves, while Emotions3D more liberally interpreted visual data to enhance the initial experience of viewers. This fairly fluid dichotomy, encouraging interactive experiences versus creating an engaging aesthetic, alerts us to the multiple priorities of contemporary museums in their curation of digital cultural heritage.

One potential solution is to provide a range of model datasets with varying degrees of applied post-processing, accompanied by the apparatus to interpret these multivalent representations. In presenting the real and the hypothetical, we can demonstrate the iterative process by which we arrived at each interpretation of the 'historical object' [Kingery-Page and Hahn 2012, 71]. This range of interpretations, while still demonstrating how to best approach each rendition, is a similar concept to providing competing interpretations of large-scale architectural reconstructions. Doing so allows viewers the opportunity to undertake their own interpretation of digital heritage objects, without deterring them, upon first viewing, with a potentially sterile rendition of the original object.

7. CONCLUSION

The two internet-based 3D heritage projects investigated in this article demonstrate different, but nonetheless equally-compelling responses to the challenges of re-creating and displaying heritage objects using 3-D photogrammetric imaging. If we are to assume that the 'uncanny' and 'the uncanny valley' are fruitful theoretical principles in this context, exploring the ways that viewers experience cognitive detachment and even discomfort when viewing unprocessed digital objects is the first stage of overcoming the effects of this phenomenon. Photogrammetric cultural heritage which 'dips' into the uncanny valley can therefore be somewhat reinvigorated through deliberate rendering in

order to generate compelling, tailored photogrammetric models. This process involves the specific application of lighting and textural effects, select tailoring of backdrops and viewing angles, and the inclusion and manipulation of culturally specific and emotionally relevant descriptive annotations. These techniques, drawn from contemporary curatorial practice, recreate realistic norms in ahistorical digital contexts, and are clearly demonstrated by the “Emotions3D: Bringing Digital Heritage to Life” project which experimented with several post-processing techniques to alert users to the material, emotional, and cultural properties of heritage objects.

Emotions3D contrasts markedly with the Smithsonian Apollo landing module project, which limited the application of post-processing techniques and encouraged users to apply their own technical interpretations to the models – with substantially different outcomes for the effects of the uncanny valley. While post-processing may play a role in shaping users’ perceptions of cultural heritage, so that 3-D reproductions are indistinguishable from their original exemplar, this is not currently possible within the technical limitations of existing photogrammetry reproduction and the confines of a digital, online format. Therefore the goal of curators should be to ensure that digital likenesses approach the realism of the original artifact; mindful that the closer objects appear to the original, the greater the likelihood that the reproduction will induce effects of the uncanny.

This paper has challenged the way we undertake “authentic reproduction” in digital environments (which may in fact deviate from a generally agreed-upon sense of realism and authenticity) in order to overcome the uncanny valley effect. This involves the artificial enhancement of the material aesthetics of heritage objects in order to eradicate perceptive uncertainty and avoid the uncanny valley altogether. As we increasingly adopt three-dimensional visualization technology within the museum experience, we can draw from existing theories of the uncanny, emotions studies, and established curatorial parameters to add depth, complexity, and diversity to the presentation of cultural heritage.

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