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Breathing life into statues using Augmented Reality

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Figure 1: *The AR app in action: The giraffe statue animates*

Abstract

AR art is a relatively recent phenomenon, one that brings innovation in the way that artworks can be produced and presented in real-world locations and environments. We present an AR art app, running in real time on a smartphone, that can be used to bring to life inanimate objects such as statues. The work relies on a virtual copy of the real object, which is produced using photogrammetry, as well as a skeleton rig for subsequent animation. As part of the work, we present a new diminishing reality technique, based on the use of particle systems, to make the real object 'disappear' and be replaced by the animating virtual copy, effectively animating the inanimate. The approach is demonstrated on two objects: a juice carton and a small giraffe sculpture.

CCS Concepts
• ***Computing methodologies*** → ***Mixed / augmented reality;*** *Animation; Image processing;* • ***Applied computing*** → *Fine arts;*

1. Introduction

Statues, which have existed since prehistoric times, are considered as one of the most acknowledged forms of public art [Tat19b]. Urban areas, such as city squares, parks and university campuses, as well as museum halls, exhibit a variety of works of three-dimensional art ranging from human or animal-like figures to sculptures of abstract shape. Artists are continually striving to push the boundaries in the way sculptural art is expressed and communicated. This paper uses the technology of Augmented Reality (AR) to build on the early twentieth century idea of *Kinetic Art* which involves the attachment of motion to artworks [Tat19a].

AR involves mixing synthetic imagery into real-time views of the real world [Azu97]. Perhaps the most famous example of this in recent years, for mobile devices, is Pokémon GO [Nia], where virtual creatures are blended into real world views. AR gives artists a new approach for creating interactive experiences [Suh18], such as in Josue Abraham's *Virtualides* exhibition, where sculptures are enriched with virtual additions and animated [Vic19].

This paper presents an AR art app that can be used to bring to life inanimate objects such as statues. This kind of effect is seen in films, for example, the ship's figurehead of Hera giving guidance in *Jason and the Argonauts* [Cha63] or the magical statue revealing the entrance to Montmarte in *Fantastic Beasts: The Crimes of Grindelwald* [Yat18]. We achieve a similar effect in real time on a smartphone.

The approach requires a virtual copy of the statue or other inanimate object to be enlivened. This is created using photogrammetry. The copy is rigged using *Blender* and a collection of animations created using poses and keyframing are stored. A particular contribution of our work is the approach for making the real statue 'disappear' and replacing it with its virtual copy so that the perceived effect is of the real statue becoming alive. To achieve this, the silhouette of the virtual copy is initially aligned with the real statue by the user. Thereafter, the user is free to move themselves and their smartphone to view the statue. A real-time background fill-in process, based on particle systems [Ree83], is used to digitally remove the real statue from the view whilst the virtual copy that replaces it animates. We believe this is the first such real-time approach presented.

The rest of this paper is organised as follows. Section 2 covers related work. Section 3 describes the techniques used in the approach. Section 4 presents and discusses the results. Finally, Section 5 presents conclusions.

2. Related Work

AR art is a relatively recent phenomenon, one that brings innovation in the way that artworks can be produced and presented in real-world locations and environments. Geroimenko describes the positive impact of AR on art by comparing Pre AR Art and AR Art, as shown in Table 1 [Ger12].

Pre AR Art in the Real World	AR Art in the Real World
Spatially limited	Spatially not limited
Expensive to produce and exhibit	Not expensive to produce and exhibit
Difficult to make interactive, animated and multimedia	Easy to make interactive, animated and multimedia

Table 1: *A Comparison between Pre AR Art and AR Art (based on a figure by [Ger12])*

AR effects have been used to transform existing works of art, allowing museum visitors to connect with paintings and explore the stories behind them, viewing them with more depth, context and background inside a smartphone app. Examples include adding 2D effects to paintings [Tec19], graffiti [Pal18] and interactive book installations [MN20].

In an unusual exhibition, visitors of New York's MoMA (Museum of Modern Art) had the opportunity to view Jackson Pollock's paintings being remixed or entirely replaced when using the MoMAR Gallery application on their smartphones [MoM19]. MoMAR is an open-source project aiming to democratize physical exhibition spaces and museums. The MoMAR app transforms the expressionist's paintings into markers or reference images and offers the users an immersive museum experience by viewing alternate artworks and exhibits.

In the "In memory of me" project, a transparent 3D model of a man taking a selfie was placed on the exact location of a statue [Far19]. The collaboration between FABERNOVEL and French artist Stéphane Simon involved an animated narcissus tattoo spreading over the statue using AR. Image recognition was employed and the virtual 3D model was accurately placed using two images on both sides (left and right) of the statue. An occlusion technique was also used so that the areas that were behind the statue could not be seen.

Gherardini *et al* [GSL19] proposed an AR application based on 3D virtual models and AR to enhance the visualization and analysis of artefacts seen in museums or archaeological sites. This project included the photogrammetric reconstruction of two roman funerary lion sculptures located in Modena, Italy and their integration into an AR app so that they could be visualized and interacted with in the real environment in an effort to enhance heritage through virtual models. A particularly interesting aspect of this approach is the support of virtual restoration since although one of the lion sculptures, which is now housed in the Museo Lapidario Estense, was damaged and missing many details, museum users could use the app to see the reconstructed sculpture.

Other recent work includes the creation of "The Last Three" mobile AR app by *INDE*, an AR company, which aimed to raise awareness of the extinction of northern white rhinos [IND17]. Once a user is located within a certain distance from a particular location, they receive a notification and the AR experience is initiated as soon as the user goes close to a marker and taps to activate it. The app brings to life a rhino, combining randomized motion and traditional animation techniques.

In these previous uses of AR, the virtual data is mixed into the real world view, either overlaying it or obscured behind part of it. In our project, separate parts of the real environment (i.e the real statue) have to be removed. As Mori *et al* [MIS17] discuss, there are various diminished reality techniques that could be employed in order to visually remove, hide or see through real objects from the real world. The state of the art approaches can be subdivided into two categories: Multi-view based approaches, which use observations from one or several additional camera locations, and patch or fragment based approaches.

Herling and Broll [HB10] attempt to remove real-world objects from a live video stream of the user's real environment by first asking the user to select the object and then utilizing an image completion algorithm that fills the selected area with information from the remaining image assuming that the object to be removed is flat. Shih *et al* [SSKH20] use context-aware colour and depth inpainting to create layered depth image representation and construct 3D photography from a single RGB-D image. The approach of Queguiner *et al* [QFR18] is based on a preliminary scan of a clean 3D scene. They identify a 3D region of interest and remove any undesired object placed in this region. In the pre-processing step, a 3D mesh is acquired and textured and the user defines the region of interest. At run-time, any objects placed in the ROI are eliminated by reusing a suitable part of the predefined texture mesh. Other image inpainting approaches, like the content-aware fill process, as used in *Adobe Photoshop*, can also help remove undesired objects from photographs, but for videos the challenge is then to maintain the coherence of the reconstructed video region.

It is clear that in recent years artists have begun to explore the possibilities that AR offers, as evidenced by the examples above. The work that we present opens up further possibilities by demonstrating that inanimate objects can appear to have life by digitally removing them from the real scene and replacing them with animating virtual counterparts in real time.

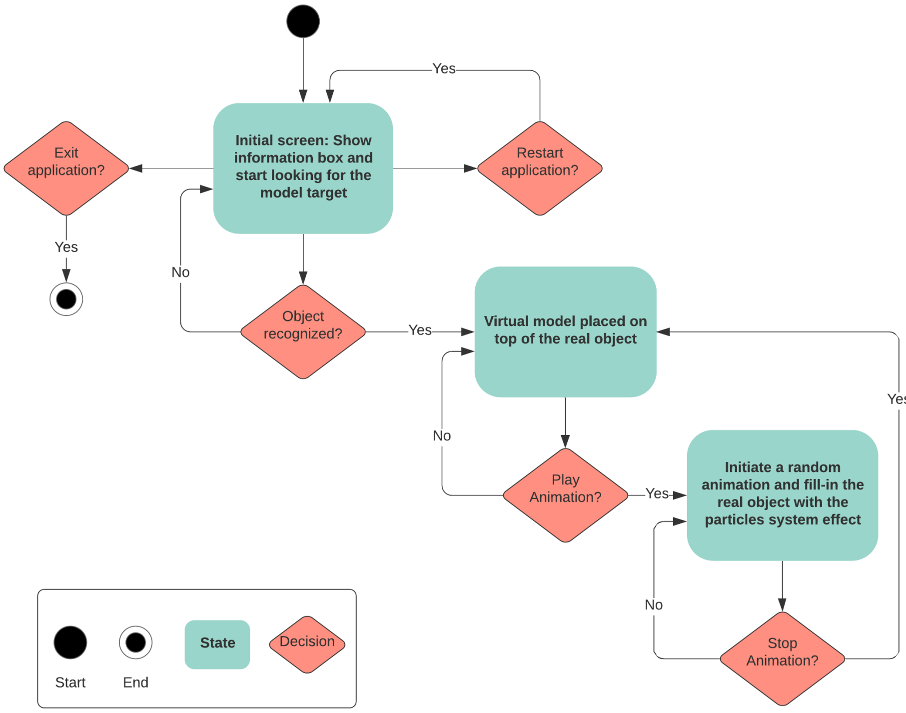


Figure 2: *State Diagram - general flow of the system*

3. Methods

Figure 2 gives an overview of the workings of the system which was developed using *Unity* and *Vuforia*. First, the virtual model of an object is fitted to its real counterpart. The user then initiates an animation effect for the virtual model by pressing the relevant button in the smartphone app. As the virtual model animates, the real model is wiped out using a particle effect. These aspects will now be described in more detail.

Photogrammetry was used to produce the virtual models of real objects. Photographs of two test objects (a juice carton and a giraffe statue) were captured using a Sony Xperia XZ1 (19MP, 25mm G Lens F2.0) and *Autodesk ReCap Photo* [Aut20] was used to produce the 3D models. Figure 3 shows some of the 92 photos captured for the giraffe sculpture. Figure 4 shows the resulting model, which is composed of 381,488 triangles. The results show that an accurate 3D model can be generated with a smartphone camera, with less than 100 photographs. For larger triangle meshes, decimation, as supported by Recap Photo, may be appropriate to maintain decent run-time display speeds. However, this was not necessary for the giraffe mesh.

After producing a model of the statue, the next step is matching

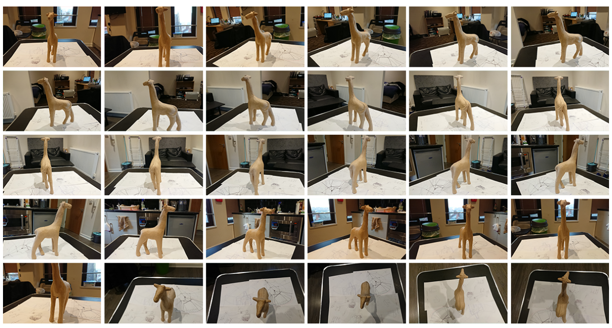


Figure 3: *Some of the images captured for the creation of the 3D model of the giraffe sculpture*

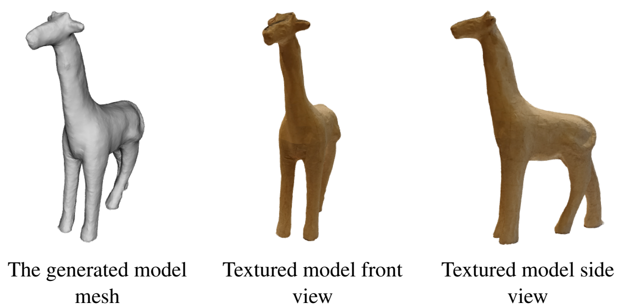


Figure 4: *Results using Autodesk ReCap Photo and supplying 92 photographs of the giraffe sculpture*

the virtual model to the real world object. The chosen approach relies on Vuforia's support for 3D object recognition and tracking of objects based on their shape [Vuf20]. User control through Vuforia's Model Targets gives an initial manual alignment of the virtual model with the real object, which is then maintained automatically. Other AR approaches could be considered (see [CCC17]). Marker-based tracking [BPF*18] could be used if the statue was labelled with easily recognisable landmarks or fixed markers. Markerless AR, using localisation and sensor technology [CCC17], could be used if the real statue was not used and the computer-generated model had to be aligned with the real world in a particular physical location.

A downside of using photogrammetry to produce a model is that the resulting mesh is not hierarchically divided into pieces, nor rigged. Either of these would make animation easier. We used *Blender* [Ble20] to rig each model with a skeleton, effectively hierarchically separating the model into interconnected parts. A range of animations were then created using poses and keyframing. Figure 5 shows the rigging for the giraffe and Figure 6 shows an animation sequence with the giraffe flexing its neck.

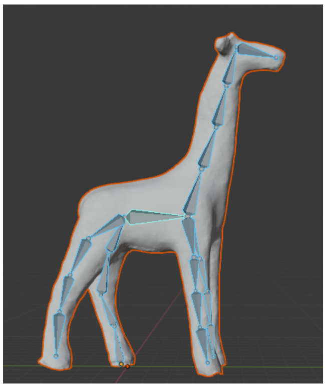


Figure 5: *Rigging of the giraffe sculpture model*

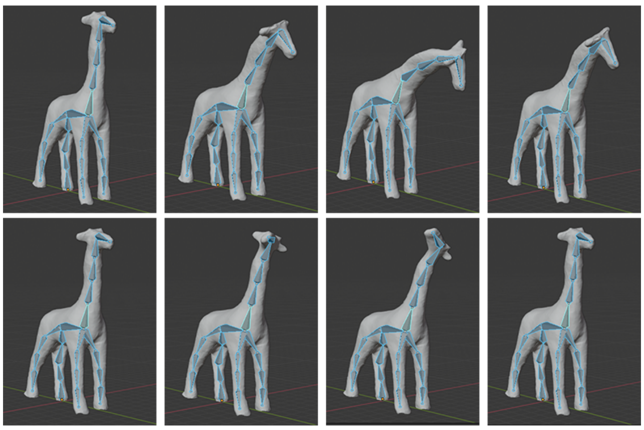


Figure 6: *The animation sequence of the giraffe sculpture model*

When the virtual model animates, the real world model must disappear to give the effect that the statue has come alive. This is achieved using a particle system effect that matches the shape of the real object. Particles are emitted in random directions from the object's vertices with each particle coloured using the colour of the real world surroundings based on the smartphone's camera image. This gives the effect of blending the real world object with its background, thus giving the impression that it has 'disappeared'.

Initial experiments assigned a local colour to each particle based on that particle's surrounding pixels. Since the computation did not reject pixels on the virtual object, particles could be coloured with the texture of the the virtual object which was undesired. Also, colouring particles individually could produce sudden colour changes if the virtual object was translating in 3D space. After any translation, when the virtual object was moving back to the initial location (where the real object and the particle system are co-located) and it was approaching the centre of the screen, the particles were being assigned a colour from the virtual object's texture.

The effect chosen finds the most frequent colour in the relevant area of the camera view and all the particles are given this colour. Iterating over all the pixels of the screen for the calculation of the most frequent colour is computationally expensive. To improve performance, every n^{th} pixel was used instead. To further reduce the amount of computation, only the central rectangular $9/25^{th}$ of screen space was used, based on the assumption that the user will be tracking the object at all times. The final algorithm accesses the colour of every 75^{th} pixel on the x and y axes of this area at the centre of the screen. The first pixel accessed is the one at the top left corner in this bounded area, then every 75^{th} pixel of the same column, and then the algorithm makes a 75-pixel step on the x-axis to access again every 75^{th} pixel on that column. Figure 7 illustrates the trade-off between the number of pixels accessed in real-time and the resulting frame rate.

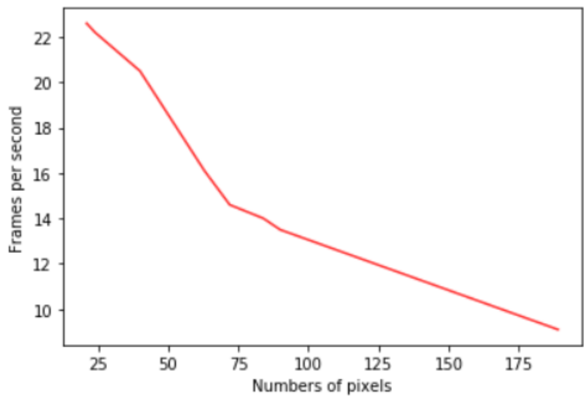
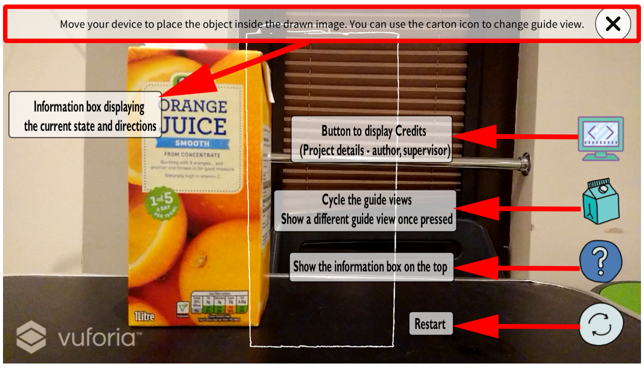
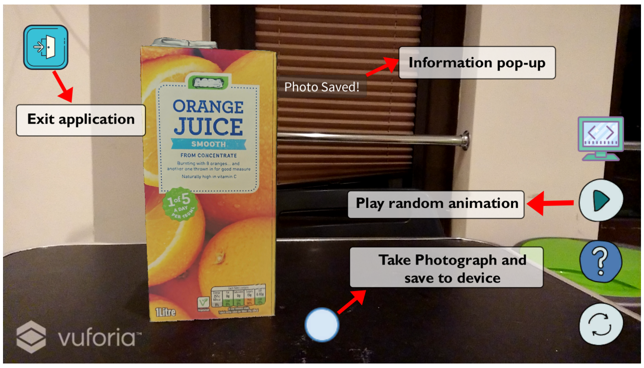


Figure 7: *Frames per second in relation to number of screen pixels accessed at run-time*

The user interface was developed based on Google's Augmented Reality Design Guidelines [Goo20]. Figure 8 shows the interface for the app. The controls are placed so that they occupy the least space of the screen possible, without being too small to neglect Fitts's law [Fit54].



The initial screen before the juice carton is recognized



Once the 3D object is recognized the virtual 3D model is placed on top of the real object

Figure 8: *Graphical User Interface: The icons and their usage*

4. Results

Figure 9 shows the system in action, with the following describing the process in detail:

- Images 1 & 2: The user is holding their device in front of the object, with the initial screen of the app being displayed. The giraffe sculpture (or the juice carton) must be placed inside the guide view in order to place the virtual model.
- Image 3: The initial screen where the user is given directions on how the object must be matched with the drawing frame to be detected and recognized.
- Image 4: Screenshot from the app displaying the state of the system once the virtual model is placed in the scene and associated with the real object.
- Image 5: The user is able to see the giraffe sculpture (or the juice carton) animating. The app immerses the user in an AR experience by perceiving the virtual model moving while it is actually standing on the table. The real sculpture/object 'disappears' and only the virtual object is seen. Even when the computer-generated model deforms in place, the parts of the real sculpture/object that were supposed to be revealed remain hidden, i.e. blended with the background.
- Images 6 & 7: The corresponding screenshots from the app displaying the object animating or deforming.
- Image 8: A user has the option to take a photograph whilst they watch the statue/object come to life. This photograph could then, for example, be posted on social media.

A video of the results is given at https://tinyurl.com/y8m5h39w. Figure 10 shows a close-up of the animating giraffe. The real giraffe sculpture is blended with the background and so appears to disappear as the virtual model moves. A user can view this real-time effect from any angle whilst the app is running. This is further illustrated in Figure 11 which shows the juice carton animating on the same table top.

The particle system effect chosen for the fill-in approach is real time. The results are good for backgrounds of low complexity, as illustrated in Figures 9, 10 and 11. However, as background complexity increases, the effect is less good. Figure 12 demonstrates the effect when the giraffe statue is stood in front of an extreme background, a changing TV screen. Since the most frequent colour is used for the fill-in effect, the real statue is removed, but is replaced by an incorrectly-coloured area that varies from frame to frame. This is complicated by the fact the user can move their smartphone at any time and view the scene from any angle. This also relates to the undesired effect that parts of the edges of the real object may remain visible. The effectiveness of the particle system fill-in effect could be improved with adjustments to the size and dimensions of the particles as well as the position of the particle system in relation to the virtual object.

Figure 13 demonstrates what happens when the real giraffe sculpture is moved behind the tracked, animating juice carton. Something similar could occur in a museum setting if, for example, a person walks past a statue. In this example, the moving object is not large, covering only a small area of the screen, and so the

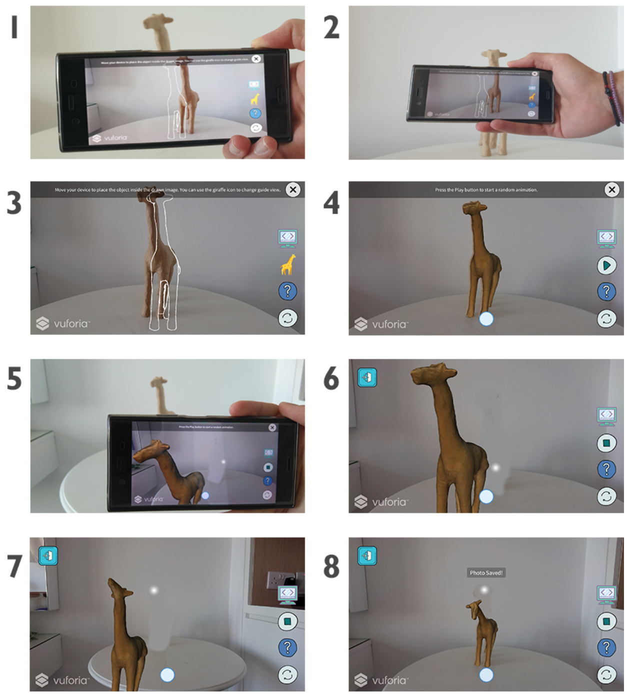


Figure 9: *The overall system in action for the giraffe sculpture*

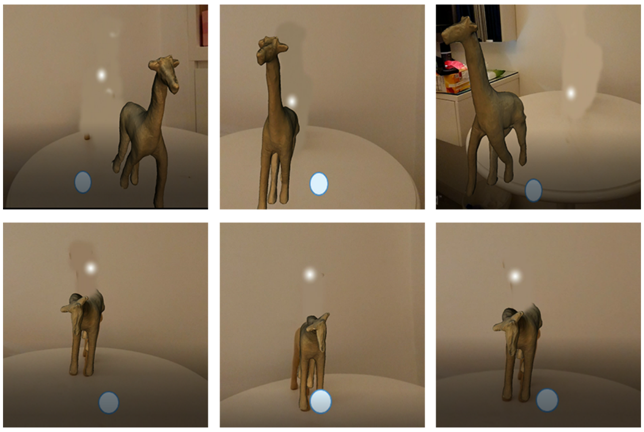


Figure 10: *Close-up screenshots from the final AR application showing the giraffe sculpture being animated*

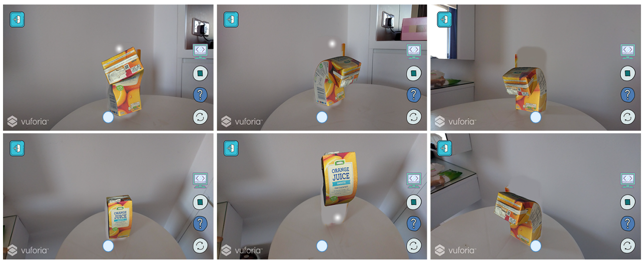


Figure 11: *Screenshots from different viewing directions while the app is running*

particle effect is not unduly affected. However, parts of the moving object, in this case the real giraffe sculpture, do disappear, lessening the overall effect. Future work would need to consider the difference between static and moving real objects when filling in.

Other improvements to the way that the screen pixels are sampled for the particle fill-in effect could be considered. As discussed in Section 3, the algorithm does not check whether the pixels that are accessed are on the virtual object (we assume that the real object is entirely covered by the particle system and there is not a possibility that the algorithm accesses pixels on the real object). A more accurate approach would reject the pixels on the virtual object and make sure that only background colours are included. A regularity term could also be considered to smooth out colour changes from frame to frame. Alternative approaches could also be employed to resolve the trade-off between the number of samples accessed at run-time and the frame rate. For example, samples could be reused for a number of consecutive frames.

A user study was conducted with six participants. Each was asked to use the software with both the giraffe sculpture and the juice carton and then complete a questionnaire. The participants were volunteers and ethics permission was obtained by following the University of Sheffield Ethics Procedure. Figure 14 shows the results of the survey, which, overall, were good. One participant said "Using AR as a means of providing a life-like movement to

Figure 12: *The background complexity affects the fill-in effect created with the particle system for the giraffe sculpture*

Figure 13: *The real giraffe sculpture is manually moved behind the animating juice carton (to simulate, say, a person, walking behind a museum exhibit). The real juice carton disappears, but so do parts of the moving real giraffe sculpture, thus lessening the overall effect.*

objects or statues can attract people visiting sites like museums since it is a unique way to share with people an alternate taste in art and culture". However, a greater number of participants would be required to give more robust findings.

The current system involves a number of manual stages. Photogrammetry must be used to initially produce a model of the real world object to be enlivened. Whilst software to accomplish this is available on modern smartphones, the results can still need manual clean-up due to object complexity or difficult capture conditions producing noisy data. In addition, the animation effects are manually produced, in our case using *Blender*. This requires some expertise. Automatic rigging (e.g. [PS12; TDS*16]) and animation of an object could be investigated for future work, although the object to be animated may also have to be recognised to make the animation appropriate. This could facilitate other realism improvements. For example, the automatic simulation of breathing could give the impression of "liveness". There is some computer graphics work on

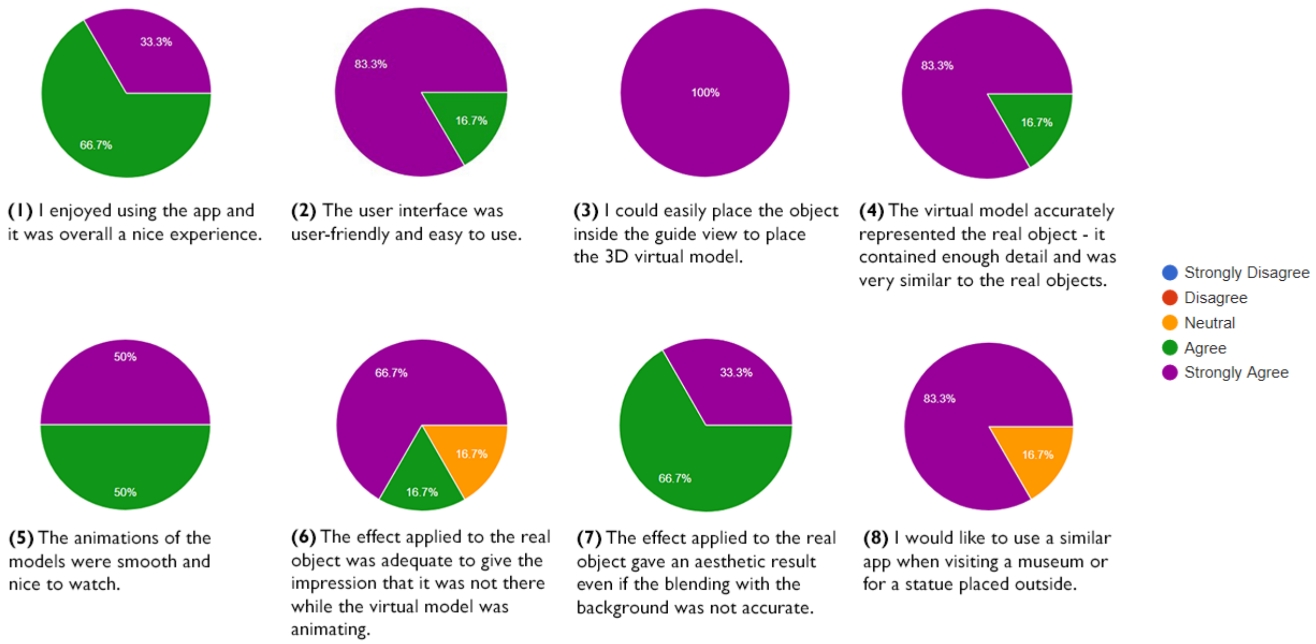


Figure 14: *The participants responds to the questionnaire: Overall, six participants used the app and completed the feedback form. Responses were recorded using a five-point Likert scale (strongly agree, agree, neutral, disagree, strongly disagree).*

respiration simulation for humans [ZCCD04; TMB14] and small posture variations and changes of balance [EMM04]. For animal-like figures such as the giraffe sculpture, a simulation of a breathing effect or a 'quiet standing' effect could be added using free-form deformations [SP86], with subtle control point variations. For breathing, parts of the mesh where the lungs are considered to be could be located and subtlely varied over time, taking into account the breathing rate of the specific animal. Randomness should also be considered to increase the perception of animacy [MFV84].

5. Conclusions

We have presented a novel AR experience, in which an inanimate object comes alive. This has been demonstrated on a giraffe sculpture and a juice carton. The current system relies on a number of initial manual steps to create a virtual model of an object and its accompanying animation rig. Whilst photogrammetry is now more commonplace, creating good virtual models still requires some expertise, and automatic approaches to model rigging and animation require further research. The particle system fill-in process produces the required diminished reality effect. However, further work is required for more complex backgrounds.

The use of AR software opens up new possibilities for artists. A virtual model and animation rig could be produced at the same time as a sculpture was being created, with the virtual model and rig being made available for use in accompanying AR software to create interactive sculptures. Our work has been demonstrated on models in indoors environments, and could also be used in museums. The next step is to work with outdoors, public sculptures. A smart city could then provide its citizens and tourists new experiences, challenging their perspective on what art is.

References

[Aut20] AUTODESK, INC. 2020. URL: https://www.autodesk.co.uk/products/recap/overview 3.

[Azu97] AZUMA, RONALD T. "A survey of augmented reality". *Presence: Teleoperators & Virtual Environments* 6.4 (1997), 355–385 1.

[Ble20] BLENDER, FOUNDATION. *2.82 — blender.org*. 2020. URL: https://www.blender.org/download/releases/2-82/ 4.

[BPF*18] BEKELE, MAFKERESEB KASSAHUN, PIERDICCA, ROBERTO, FRONTONI, EMANUELE, et al. "A Survey of Augmented, Virtual, and Mixed Reality for Cultural Heritage". *J. Comput. Cult. Herit.* 11.2 (Mar. 2018). ISSN: 1556-4673. DOI: 10.1145/3145534. URL: https://doi.org/10.1145/3145534 4.

[CCC17] CHENG, JACK, CHEN, KEYU, and CHEN, WEIWEI. "Comparison of marker-based AR and markerless AR: A case study on indoor decoration system". July 2017. DOI: 10.24928/JC3-2017/0231 4.

[Cha63] CHAFFEY, DON (DIRECTOR). *Jason and the Argonauts*. Columbia Pictures. 1963 1.

[EMM04] EGGES, ARJAN, MOLET, TOM, and MAGNENAT-THALMANN, NADIA. "Personalised real-time idle motion synthesis". *12th Pacific Conference on Computer Graphics and Applications, 2004. PG 2004. Proceedings.* IEEE. 2004, 121–130 7.

[Far19] FARNIER, THIBAULT. 2019. URL: https://www.fabernovel.com/en/engineering/modernizing-art-with-augmented-reality 2.

[Fit54] FITTS, PAUL M. "The information capacity of the human motor system in controlling the amplitude of movement". *Journal of experimental psychology* 47.6 (1954), 381 4.

[Ger12] GEROIMENKO, VLADIMIR. "Augmented Reality Technology and Art: The Analysis and Visualization of Evolving Conceptual Models". *2012 16th International Conference on Information Visualisation* (2012) 2.

[Goo20] GOOGLE. 2020. URL: https://designguidelines.withgoogle.com/ar-design/ 4.

[GSL19] GHERARDINI, FRANCESCO, SANTACHIARA, MATTIA, and LEALI, FRANCESCO. "Enhancing heritage fruition through 3D virtual models and augmented reality: an application to Roman artefacts". *Virtual Archaeology Review* 10.21 (2019), 67. DOI: 10.4995/var.2019.11918 2.

[HB10] HERLING, JAN and BROLL, WOLFGANG. "Advanced self-contained object removal for realizing real-time diminished reality in unconstrained environments". *2010 IEEE International Symposium on Mixed and Augmented Reality*. IEEE. 2010, 207–212 2.

[IND17] INDE. 2017. URL: https://www.indestry.com/news/2017/10/22/the-last-three-northern-white-rhinos-to-be-digitally-resurrected-in-new-york-using-augmented-reality 2.

[MFV84] MARION, ANN, FLEISCHER, KURT, and VICKERS, MARK. "Towards expressive animation for interactive characters". *Proc. Graphics Interface*. Vol. 84. 1984, 17–20 7.

[MIS17] MORI, SHOHEI, IKEDA, SEI, and SAITO, HIDEO. "A survey of diminished reality: Techniques for visually concealing, eliminating, and seeing through real objects". *IPSJ Transactions on Computer Vision and Applications* 9.1 (2017). DOI: 10.1186/s41074-017-0028-1 2.

[MN20] MOVERS and NYC, SHAKERS. 2020. URL: https://www.moversandshakersnyc.com/ar-book 2.

[MoM19] MOMAR. 2019. URL: http://momar.gallery/about.html 2.

[Nia] NIANTIC, INC. *Pokémon GO*. URL: https://www.pokemongo.com/en-gb/ 1.

[Pal18] PALUMBO, JACQUI. *Street Artist Escif Is Using Augmented Reality to Challenge the Boundaries of Graffiti*. 2018. URL: https://www.artsy.net/article/artsy-editorial-street-artist-escif-augmented-reality-challenge-boundaries-graffiti 2.

[PS12] PANTUWONG, NATAPON and SUGIMOTO, MASANORI. "A novel template-based automatic rigging algorithm for articulated-character animation". *Computer Animation and Virtual Worlds* 23.2 (2012), 125–141. DOI: 10.1002/cav.1429 6.

[QFR18] QUEGUINER, GLEN, FRADET, MATTHIEU, and ROUHANI, MOHAMMAD. "Towards mobile diminished reality". *2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*. IEEE. 2018, 226–231 2.

[Ree83] REEVES, WILLIAM T. "Particle systems—a technique for modeling a class of fuzzy objects". *ACM Transactions On Graphics (TOG)* 2.2 (1983), 91–108 2.

[SP86] SEDERBERG, THOMAS W and PARRY, SCOTT R. "Free-form deformation of solid geometric models". *Proceedings of the 13th annual conference on Computer graphics and interactive techniques*. 1986, 151–160 7.

[SSKH20] SHIH, MENG-LI, SU, SHIH-YANG, KOPF, JOHANNES, and HUANG, JIA-BIN. "3D Photography using Context-aware Layered Depth Inpainting". *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*. 2020 2.

[Suh18] SUHR, H. C. "The Audience and Artist Interactivity in Augmented Reality Art: The Solo Exhibition on the Flame Series". *Critical Arts* 32.3 (2018), 111–125 1.

[Tat19a] TATE. 2019. URL: https://www.tate.org.uk/art/art-terms/k/kinetic-art 1.

[Tat19b] TATE. *public art, art term*. 2019. URL: https://www.tate.org.uk/art/art-terms/p/public-art 1.

[TDS*16] TAGLIASACCHI, ANDREA, DELAME, THOMAS, SPAGNUOLO, MICHELA, et al. "3D Skeletons: A State-of-the-Art Report". *Computer Graphics Forum* 35.2 (2016), 573–597. DOI: 10.1111/cgf.12865 6.

[Tec19] TECHNOLOGY, FACEBOOK. 2019. URL: https://tech.fb.com/augmenting-abstraction-facebook-expands-ar-experiences-with-tate-britain/ 2.

[TMB14] TSOLI, AGGELIKI, MAHMOOD, NAUREEN, and BLACK, MICHAEL J. "Breathing Life into Shape: Capturing, Modeling and Animating 3D Human Breathing". *ACM Trans. Graph.* 33.4 (July 2014). ISSN: 0730-0301. DOI: 10.1145/2601097.2601225. URL: https://doi.org/10.1145/2601097.2601225 7.

[Vic19] VICE. 2019. URL: https://www.vice.com/en_uk/article/ez5bb4/sculptures-come-to-life-in-an-augmented-reality-art-gallery 1.

[Vuf20] VUFORIA, LIBRARY. *Model Targets*. 2020. URL: https://library.vuforia.com/features/objects/model-targets.html 4.

[Yat18] YATES, D (DIRECTOR). *Fantastic Beasts: The Crimes of Grindelwald*. Warner Bros. Pictures. 2018 1.

[ZCCD04] ZORDAN, VICTOR BRIAN, CELLY, BHRIGU, CHIU, BILL, and DILORENZO, PAUL C. "Breathe Easy: Model and Control of Simulated Respiration for Animation". *Proceedings of the 2004 ACM SIGGRAPH/Eurographics Symposium on Computer Animation*. SCA '04. Grenoble, France: Eurographics Association, 2004, 29–37. ISBN: 3905673142. DOI: 10.1145/1028523.1028528. URL: https://doi.org/10.1145/1028523.1028528 7.