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| **Institution:** University of Bath | |
| **Unit of Assessment:** B11 Computer Science and Informatics | |
| **Title of case study:** Fast and Efficient Facial Performance Capture and Animation | |
| **Period when the underpinning research was undertaken:** 2007-2020 | |

**Details of staff conducting the underpinning research from the submitting unit:**

| Name(s):<br><br>Darren Cosker | Role(s) (e.g. job title):<br><br>Professor, previously Reader, Lecturer and Royal Academy of Engineering & EPSRC Research Fellow | Period(s) employed by submitting HEI:<br>July 2007 - Present |
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| **Period when the claimed impact occurred:** August 2013-December 2020 | |
| **Is this case study continued from a case study submitted in 2014?** N | |

**1. Summary of the impact**

Facial animation is frequently used across the entertainment industry for movies and video games. Prof. Cosker's research has led to the development of new tools and technologies to create facial animation which enable typically time-consuming tasks to be performed quickly and within limited resources. These tools have been used through the EPSRC Centre for the Analysis of Motion, Entertainment Research and Applications (CAMERA) at the University of Bath, by major broadcasting corporations (BBC), world-leading film & animation (Aardman animation) and creative studios (Marshmallow Laser Feast and Satore Studios) to enable them to produce higher quality facial animation more efficiently. This has led to the creation of award-winning animations that have enriched cultural experiences for audiences across the globe.

**2. Underpinning research**

It has always been a challenge across the video game and movie industries to create facial animation quickly and at high quality without expensive resources (e.g., human effort and facilities) and/or specialist expertise. Over the last 12 years, Prof. Cosker has performed research in this area – understanding faces and their movement – and developed methodologies to create facial animation more efficiently.

Between 2007 and 2012, Prof. Cosker used 4D imaging technology to acquire the first database [R1] of psychologically validated facial Action Units (AUs) according to the Facial Action Coding System (FACS) created by Dr. Paul Ekman – an American Psychologist who pioneered our understanding of facial emotion with the publication of FACS in the 1970s. This allowed Cosker to observe, for the first time, dynamic facial movements in 3D during AUs. Part of processing the data included a method to track faces using a novel Active Appearance Model (AAM) formulation that was trained on the fly using key-frames [R1]. The method for tracking movement in faces was later improved by introducing mesh based optical flow [R2], which greatly improved the 3D alignment and registration of facial meshes. While working on a RAEng Fellowship [G1] that developed methods for 3D facial capture and tracking, Cosker began collaborating with Oliver James (Chief Scientist) and Martin Parsons (Head of Creative Animation) at Double Negative Visual Effects – now DNEG; Martin Parsons now heads the CAMERA studio. DNEG, one of the world's leading visual effects studios with multiple Oscar wins, required a solution to track actors' faces from Head Mounted Cameras (HMCs) while working on the Disney movie John Carter and turned to Prof Cosker. Testing the feasibility of Cosker's facial tracking solutions on DNEG test footage led to the development of a tool called 'Kojak', used in the movie on over 200 shots. Prof. Cosker then won a four year Royal Society Industry fellowship (50% hosted at DNEG [G2]), during which his research added an assessment of modern camera tracking approaches in VFX and further developed facial animation [R2].

Between 2011 and 2013, Cosker developed a new method for real-time animation that preserves rigid areas defined in the texture map; this was shown to work on facial animations where the character was reptilian or had scales [R3]. Cosker proposed use cases for this technology leading to patents with Disney Research.

This research underpinned later work (2014 – present) to automatically estimate action units on facial animation models using motion capture [R4]. In an InnovateUK project with The Imaginarium [G3] the motion capture research was developed further and Cosker devised an end-to-end pipeline to build facial models for actors from a single 3D scan of their face which could then be animated quickly at high quality using motion capture. This collaboration underpinned the establishment of CAMERA (now a GBP20,000,000 research centre) and resulted in a novel optimisation scheme and a new method to acquire motion information 'in between' motion capture markers, i.e., on skin features. More recently, Cosker extended the work further to enable faces to be animated quickly by unskilled users – even children [R5]. This is being explored in experiments with psychiatric patients with Prof. Essi Viding (UCL) and Dr. Isabelle Mareschal (QMU) as part of an MRC grant [G4].

## 3. References to the research

[R1] Reed, K & Cosker, D 2019, 'User-Guided Facial Animation through an Evolutionary Interface', *Computer Graphics Forum*, vol. 38, no. 6, pp. 165-176.
https://doi.org/10.1111/cgf.13612

[R2] Ravikumar, S, Davidson, C, Kit, D, Campbell, NDF, Benedetti, L & Cosker, D 2016, Reading Between The Dots: Combining 3D Markers And FACS Classification For High-Quality Blendshape Facial Animation. in K Moffatt & T Popa (eds), *Proceedings of Graphics Interface 2016: Victoria, British Columbia, Canada, 1- 3 June 2016 .* Canadian Human-Computer Communications Society, Ontario, Canada, pp. 143-151.
https://doi.org/10.20380/GI2016.18

[R3] Cosker, D, Krumhuber, E & Hilton, A 2012, A FACS valid 3D dynamic action unit database with applications to 3D dynamic morphable facial modeling. in *2011 IEEE International Conference on Computer Vision (ICCV).*, 6126510, International Conference on Computer Vision, IEEE, pp. 2296-2303, 13th International Conference on Computer Vision (ICCV), Barcelona, Spain, 6/11/11. https://doi.org/10.1109/ICCV.2011.6126510

[R4] Li, W, Cosker, D, Brown, M & Tang, R 2013, Optical flow estimation using Laplacian Mesh Energy. in *2013 IEEE Conference on Computer Vision and Pattern Recognition.* IEEE Conference on Computer Vision and Pattern Recognition, vol. 2013, IEEE, pp. 2435-2442, IEEE International Conference on Computer Vision and Pattern Recognition (CVPR), Oregon, US, UK United Kingdom, 25/06/13. https://doi.org/10.1109/CVPR.2013.315

[R5] Koniaris, C, Cosker, D, Yang, X, Mitchell, K & Matthews, I 2013, Real-time content-aware texturing for deformable surfaces. in *CVMP '13: Proceedings of the 10th European Conference on Visual Media Production.*, 11, Association for Computing Machinery, pp. 1-10. https://doi.org/10.1145/2534008.2534016

The research underpinning this case study was based on the following grants (all with Prof. Cosker as PI).

[G3] 2015-2017: Goal Oriented Real Time Intelligent Performance Retargeting (GBP29,997 FEC). Partner: The Imaginarium. **Innovate UK**.

[G4] 2019-2022. A tool to reveal Individual Differences in Facial Perception (GBP402,113) **Medical Research Council (MRC)**

[G5] 2016-2018. HARPC: HMC for Augmented Reality Performance Capture (GBP119,025, Total project value GBP517,616 FEC). Partner: The Imaginarium. **Innovate UK**

[G6] 2015-2020: Centre for the Analysis of Motion, Entertainment Research and Applications - CAMERA 1.0 (GBP4,998,728 FEC).

[G7] 2020-2025: Centre for the Analysis of Motion, Entertainment Research and Applications – CAMERA 2.0 (GBP4,150,000 FEC).

**4. Details of the impact**

Through CAMERA, Cosker's research insights into facial motion capture (R1 – R5) have enhanced VR production in resource constrained environments, yielding high quality, realistic, award-winning films and games that have reached world-wide audiences.

**Enhancing the quality and efficiency of VR film production**

**'Chameleon' – Marshmallow Laser Feast**. A 2016 collaboration (with the commissioner British Council, creative agency Marshmallow Laser Feast (MLF) and local artists) co-created 'Chameleon', a VR film about the community in Mexico City. This used Cosker's '3D scan to actor' tool to generate high quality 3D facial models in a time-scale that met the tight constraints of their project: *"without the use of CAMERA's technology, MLF would not have been able to deliver the 3D facial models for the project quickly enough and at the level of realism desired"* [S1; Executive Producer, MLF]. 'Chameleon' has attracted world-wide audiences and enriched cultural experiences through exhibitions such as the 15-day International Documentary Film Festival Amsterdam (IDFA; 2016) which included a Dutch royal visit, 2 exhibits at MUTEK (Mexico City, 2016) and the VR World Congress 2016, with approximately 14,000 visitors across these exhibits. MLF have demonstrated the film to the BBC audience development/marketing team, and CAMERA have demonstrated it to more than 200 visitors [S1].

**'Is Anna OK?' – Aardman Animation**. 'Is Anna OK?' is a VR experience created from a commercial project collaboration between CAMERA, Aardman and BBC, utilising the '3D scan to actor' tools together with motion capture to produce a user and production-friendly facial motion capture and modelling solution [S2] to create lifelike characters. It tells a true story of the personal repercussions of brain trauma from different perspectives. In 2018 'Is Anna OK?' was made available on the Oculus Store to download, was part of a national press campaign by the BBC, toured at multiple festivals and was used to raise awareness of brain injury by Headway [S3]; the related YouTube video has more than 16,000 views. CAMERA's role was crucial: "*Collaborating with CAMERA and making use of their facial animation technology made the final experience richer and possible within a tight budget. The animation CAMERA produced was core to delivering the experience of Anna and her family. They have been touched by what has been created and are glad others will get to hear their story and that awareness of brain injury will be raised further*" [S2; Head of Interactive Production, Aardman Animation].

**Cosmos Within Us – Satore Studios.** CAMERA worked with Satore Studios [S3] on 'Cosmos Within Us' (2019) to tell the story of a 60-year-old man suffering from Alzheimer's. Satore required photorealistic characters to achieve their vision but had no access to affordable technology that would deliver the required quality. The University of Bath's facial motion capture tools created performances that were key to the immersive experience,

allowing Satore to deliver high quality animation on time and on budget. CAMERA tools *"were critical to delivery of the experience due to the presence of the character during the piece. The use of the grandmother in the space, made for a new form of interaction between viewer and haptics, which would be very hard to replicate every time, unless it was recorded"* [S3; Creative Director and Founder, Satore Studio]. 'Cosmos within Us' has won critical acclaim, debuting at the Cannes film festival and subsequently shown 132 times at the Venice Film Festival (2019) [S5] and 40 times at the Raindance Film festival (2019), where it won the prestigious best immersive experience award [S6].

**Related projects:**

- '11:11 Memories Retold'. Created with Bandai Namco and Aardman (their first video game [S7]), CAMERA created all of the motion capture for this video game, nominated for a BAFTA in 2019 [S8], won the TIGA award for Best Educational or Serious Game [S9] and is available on XBox One, PC and PS4 [S7].

- 'Magic Butterfly', a VR experience created with the Welsh National Opera and REWIND where the viewer could watch lead soprano Kara Son perform in the opera Madame Butterfly. CAMERA created all of the animation of Kara performing using its motion capture technology, therefore contributing the essential part of this experience. The piece has won several awards, including Creative Technology Award (Gold Winner) and Immersive Art Award (Gold Winner) and was attended by more than 12,000 people in 2017, touring in the UK and Hong Kong, Copenhagen and Dubai [S9].

- Johnnie Walker HIK+ campaign with Satore studio, including creation of dance animation for a performer captured by CAMERA and projected for 5 days onto the side of a large public building (Torre Reforma) on one of the most important avenues in central Mexico City in 2017. The experience engaged 120,000 people and generated 63,000,000 brand impacts [S10].

**5. Sources to corroborate the impact**

[S1] Evidence letter: Executive Producer of Marshmallow Laser Feast, 8 December 2020

[S2] Evidence letter: Head of Interactive Production at Aardman Animation, 8 December 2020.

[S3] Headway Press Release, 25 October 2018 Headway teams up with BBC Stories to explain brain injury in VR project. https://www.headway.org.uk/news-and-campaigns/news/2018/headway-teams-up-with-bbc-stories-to-explain-brain-injury-in-vr-project/

[S4] Evidence letter: Creative Director and Founder of Satore Studio, 31 December 2020.

[S5] Venice Biennale website, 2019. Cosmos within us: Venice virtual reality. https://www.labiennale.org/en/cinema/2019/venice-virtual-reality/cosmos-within-us

[S6] Raindance Film Festival website, 2019. Raindance immersive award winners presented by Bose. 29 September. https://www.raindance.org/raindance-immersive-award-winners-presented-by-bose/

[S7] Aardman website, 2019, 11-11: Memories Retold. https://www.aardman.com/work/11-11-memories-retold-game/

[S8] BAFTA website, 2019. https://www.bafta.org/games/awards/british-game-2019

[S9] TIGA Games Industry Awards website, 2019 Winners https://tiga.org/awards/2019-winners

[S10] Welsh National Opera website, 2017/2018. Magic Butterfly. https://wno.org.uk/archive/2017-2018/magic-butterfly

[S11] Satore Studio website, 2017. HIK+. https://satorestudio.com/portfolio_page/hik/