Institution: Bournemouth University

Unit of Assessment: 32

Title of case study: Developing character animation techniques to improve production practice in the animation sector and create economic impact on Humain Ltd.

Period when the underpinning research was undertaken: 2008 – 2020

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

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Shaojun Bian	Research Associate	02/2018 – 02/2020
Professor Lihua You	Professor	04/1999 – current
Professor Jian J. Zhang	Professor of Computer Animation	01/1996 – current
Jon Macey	Senior Lecturer Computer Animation	05/1997 – current

Period when the claimed impact occurred: 01/08/2013 –31/12/2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 100 words)

Producing high-quality character animation involves a significant amount of time-consuming manual work, making character animation production difficult and inefficient. Research from Bournemouth University (BU) tackled this problem, resulting in an improvement in production practices and economic impact for Humain Ltd, using BU's newly developed character animation techniques. These newly developed techniques:

- reduced the time needed to create a facial rig from several weeks to several minutes,
- helped Humain Ltd. attract GBP1,096,000 investments and generate GBP1,153,000 revenue in 3 years,
- and helped Humain Ltd. become a world-leading technology and entertainment leader with high-quality products and services.

2. Underpinning research (indicative maximum 500 words)

In 2019, the global animation market was valued approximately USD335,700,000,000 (Market Watch, 2021). This demand places significant pressures on animation studios to produce high-quality virtual characters in a short time scale, which involves tedious and time-consuming manual work. Since 2008, BU researchers have tackled this problem, leading to:

- The development of two new techniques:
  1. Characteristic curve-based dynamic skin deformation [R1] and,
  2. Efficient numerical dynamic skin deformation to create a horse animation of 30 frames in less than 0.5 seconds [R2].
- A European Commission funded research project (2018-2021, EUR535,500) to develop new techniques [T1] and their software tools [S1] of partial differential equation-based geometric modelling, image processing and shape reconstruction (PDE-GIR).
- An Innovate UK funded Knowledge Transfer Partnership (KTP) project (2018-2020, GBP173,010) to develop new techniques of facial blendshapes [R3, R7]. The completed

KTP project was awarded the highest grade of "Outstanding" by the KTP Grading Panel for its achievement in meeting KTP's objectives.

BU's research findings can be summarised as follows:

Facial rigging tools

a) Hybrid facial rigging tool. This newly developed tool integrates facial blendshapes and bone-driven facial animation to create various facial expressions easily and quickly [R3].
b) Automatic correspondences for deformation transfer. To tackle the problem of deformation transfer in manually specifying correspondences of facial landmarks, this newly developed technique achieves full automation and avoids manual operations [R3]. This formed the basis of another Innovate UK funded project led by Humain Ltd. to develop a new technique of immersive hands.
c) Machine learning-based 3D facial expression production. This technique combines a 3D face morphable model with machine learning to reuse existing datasets for reducing manual work in producing facial animation from a single image [awaiting publication].

Skin deformation techniques

a) Automatic rigging. Manually placing a skeleton in a 3D character model involves heavy manual operations. This newly developed technique automates the process and creates an animation skeleton in a few milliseconds [R4].
b) Analytical physics-based skin deformation. This technique [R5] was developed to tackle the difficulty in implementing the numerical dynamic skin deformation technique [R2] and achieve higher efficiency. It obtains the first analytical solution to physics-based skin deformations to create the animation of a horse model with 10,128 vertices at 205 frames per second [R5].

Character modelling methods

a) Fast character modelling with sketch-based partial differential equation (PDE) surfaces. To tackle the incapability of sketch-based modelling in creating detailed 3D models easily and quickly, this project developed a simple, easy-to-use, efficient, and sketch-based character modelling tool for fast creation of detailed character models [R6].
b) Character model creation with ordinary differential equation (ODE) based C^2 continuous surfaces. This technique was developed to avoid tedious and time-consuming manual operations of existing techniques in stitching two separate patches together to achieve the required continuities, significantly reduce data size, and provide more flexible and powerful shape manipulation handles [R7].

3. References to the research (indicative maximum of six references)

R1-R7 are peer-reviewed journal publications. Bournemouth University and Humain Ltd have been awarded a Certificate of Excellence of Knowledge Transfer Partnerships (KTP010860) issued by Innovate UK. The certificate is to certify that their KTP was awarded the highest grade of "Outstanding" by the KTP Grading Panel for its achievement in meeting KTP's objectives.

R1. You, L., Yang, X. and Zhang, J. J. (2008), "Dynamic skin deformation with characteristic curves," *Computer Animation and Virtual Worlds* 19: pp. 433-444. https://doi.org/10.1002/cav.235

R2. Chaudhry, E., Bian, S., Ugail, H., Jin, X., You, L. and Zhang, J. J. (2015), "Dynamic skin deformation using finite difference solutions for character animation," *Computers and Graphics* 46: pp. 294-305. https://doi.org/10.1016/j.cag.2014.09.029

R3. Bian, S., Zheng, A., Gao, L., Maguire, G., Kokke, W., Macey, J., You, L. and Zhang, J.J. (2020), "Fully automatic facial deformation transfer," *Symmetry* 12(1): 27. https://doi.org/10.3390/sym12010027

R4. Bian, S., Zheng, A., Chaudhry, E., You, L. and Zhang, J. J. (2018), "Automatic generation of dynamic skin deformation for animated characters," *Symmetry* 10(4): 89. https://doi.org/10.3390/sym10040089

R5. Bian, S., Deng, Z., Chaudhry, E., You, L., Yang, X., Guo, L., Ugail, H., Jin, X., Xiao, Z. and Zhang, J. J. (2019) "Efficient and realistic character animation through analytical physics-based skin deformation," *Graphical Models* 104: 101035. https://doi.org/10.1016/j.gmod.2019.101035

R6. You, L., Yang, X., Pan, J., Lee, T., Bian, S., Qian, K., Habib, Z., Bux, A., Kamzi, I. and Zhang, J. J. (2020), "Fast character modeling with sketch-based PDE surfaces," *Multimedia Tools and Applications* 79: pp. 23161-23187. https://doi.org/10.1007/s11042-020-09060-9

R7. Bian, S., Maguire, G., Kokke, W., You, L., Zhang, J. J. (2020), "Efficient C2 continuous surface creation technique based on ordinary differential equation," *Symmetry* 12(1): 38. https://doi.org/10.3390/sym12010038

New PDE-GIR techniques

T1. Bournemouth University et al. (2019). *D1.2: PDE modelling techniques*. [online] European Commission. Available at: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c4bd3e85&appId=PPGMS [Accessed 11 December 2020].

Software

S1. Bournemouth University et al. (2020). *D1.4: PDE software and user guide*. [report] European Commission. Available on request.

4. Details of the impact (indicative maximum 750 words)

Producing high-quality character animation involves time-consuming manual work, making its production difficult and inefficient. Humain Ltd. aims to create the world's best automated online character creation service through new techniques, to produce high-quality virtual characters and their animation efficiently.

Dr Shaojun Bian was employed via the KTP to develop new techniques [R3, R7: E1, E3, E4]. She previously researched automatic rigging and skin deformation [R2, R4] as part of the European Commission funded PDE-GIR project (http://pde-gir.com/). The new techniques developed by the PDE-GIR project have been applied in Indeform Ltd. [E3], disseminated to many audiences through two PDE-GIR workshops [E4], and provided a foundation for the subsequent KTP [E5] and resulting impact [E2, E6].

As Humain Ltd. highly appraised, "BU development of the facial rigging tools and techniques for skin deformation, machine learning-based 3D facial expression, fast character modelling with sketch-based PDE surfaces and automatic rigging has given the company an edge over the competition, enabling the company to use photographic and video input into their process instead of a scan as well as use algorithms" [E6].

Impact on industry practices

Before developing the new techniques, getting a 3D virtual character into production required between a few days to a few months. The new techniques [E1, E2] enabled Humain Ltd. to automate the transfer of Action Units from their own database to another character, removing the need for 3D modellers, which "reduced the time frame to create complete models with realistic facial expressions from 30 days to a few minutes" [E2, E6]. This is a significant time and cost saving to Humain Ltd.

As well as saving time, the new techniques have helped to make Humain Ltd.'s workload more streamlined and efficient. Producing high-quality 3D virtual character requires experts, modellers and animators from different disciplines to work together, and heavy and time-consuming

manual operations are involved in the production process. The new techniques have been integrated into the company's product offerings, transformed the company's facial development pipeline from a labour-intensive process by highly specialized artists to a simple command line interface that everyone in the company can run. According to Humain, this has "enabled [them] to develop technology and capability that has moved the company from being purely considered as an outsource vendor to a state-of-the-art R&D partner to world leading technology and entertainment leaders" [E2, p.6-8].

The impact on industry practices is also highlighted by Indeform Ltd.'s comments: the main benefits of PDE-based modelling Blender plugin [S1] application in medical and engineering areas are "Flexibility and ability" and "Speed of predefined models generation", "it takes seconds to generate new model", and "This is a huge benefit" [E3].

Impact on innovation

Transforming Humain Ltd.'s ways of working has changed its external reputation. As Humain Ltd. stated, "the game-changer contribution of BU researchers" has enabled the company "to achieve its goals while reducing the time and effort required to create a facial rig, which is a breakthrough which has and will become a huge profit centre for the company as it enables Humain to complete industry leading facial rigs with much fewer resources" [E6].

The techniques developed by BU researchers at Humain Ltd. have made it possible for them to "work on cutting edge projects with world-leading organisations in the technology and entertainment industry, such as Activision and Google, sign contracts to expand our portfolio and services (e.g. Axis Studios and The Imaginarium) and obtain further funding to develop our technology which have placed us as a reference in a highly competitive business market" [E6].

Economic impact

Humain's increased competitiveness is demonstrated by the following examples:

- Humain Ltd. was asked by leading entertainment organisation HBO to provide the evidence of developing non-photorealistic (NPR) characters. With the new techniques, Humain Ltd. delivered a fully realised NPR character with animation running inside the Unreal Engine, 24 hours later. Humain Ltd. won the USD400,000 contract [E2, p.8], beating two other competitors.
- The Imaginarium Studios required rigging characters for an innovative television show for a world leading streaming company. Using the developed techniques, Humain Ltd. offered a unique approach to capturing the actors' movement and won the contract [E2, p.8].
- The developed techniques contributed to the successful delivery of a GBP500,000 project to Microsoft [E2, p.11].
- The developed techniques served as the basis for a successful application to the Audience of the Future Immersive Technology Investment Accelerator in 2019. The company secured GBP90,000 in equity investment from TechStart NI and GBP210,000 from Innovate UK [E2, p.6].
- Over the past 3 years, the company has worked on 16 different projects, generating a revenue of GBP1,153,000 [E6].

5. Sources to corroborate the impact (indicative maximum of 10 references)

E1. Bian, S. (2020). Associate Final Report Form. Innovate UK KTP010860. Bournemouth: Bournemouth University, pp.1-18.

E2. Zhang, J. and Maguire, G. (2020). Partners Final Report Form. Innovate UK KTP010860. Bournemouth: Bournemouth University, pp.1-30.

E3. Indeform Ltd. (2020). *D1.5: INDEFORM Ltd WP1 Report*. PDE-based Geometric modelling, Image processing, and shape Reconstruction. Kaunas: INDEFORM Ltd, pp.1-8.

E4

E4a. EasyChair Smart CFP. (2019). *SKIMA2019 and #AIMaldives2019: 13th International Conference on Software, Knowledge, Information Management and Applications and the International Workshop on Applied Artificial Intelligence*. Available at: https://easychair.org/cfp/SKIMA2019andAIMaldives2019. (Accessed: 26 February 2021).
E4b. International Conference on Computational Science. (2020). *Thematic Tracks*. Available at: https://www.iccs-meeting.org/iccs2020/thematic-tracks/. (Accessed: 26 February 2021).
E4c. International Conference on Computational Science. (2021). *Thematic Tracks*. Available at: https://www.iccs-meeting.org/iccs2021/thematic-tracks/. (Accessed: 26 February 2021).

E5. KTP Funding Application. (2018). 1024769 - HUMAIN LIMITED & Bournemouth University, Innovate UK, GBP171,450, 14/02/2018 – 13/02/2020.

E6. Humain Ltd. (2021). Testimonial letter, 15 January.