Institution: Bournemouth University
Unit of Assessment: UOA34
Title of case study: Improved Motion Blur in Computer Animated Film and Special Effects.
1. Summary of the impact (indicative maximum 100 words)

Motion blur is the effect that occurs when objects are filmed at speed. Researchers at Bournemouth University's (BU) National Centre for Computer Animation (NCCA) developed a new approach to more accurately model this effect in 3D image production. This produces aesthetically superior images without any penalty in rendering time. The technique was implemented by Pixar in their own films and in the commercial PRMan software they supply to other animation and effects studios in New Zealand, Canada, the USA and the UK, among others. As well as contributing significantly to Pixar's revenue, the technique improves the viewing experience and has been used on virtually every major feature film produced since 2008. This contributes to the global animation industry worth $207 US billion (2012, R1).

2. Underpinning research (indicative maximum 500 words)

In 2011 the NCCA won the Queen's Anniversary Prize for Higher and Further Education in recognition of its contribution to world-leading excellence and pioneering development in computer animation.

A clear example of this industry-shaping work is the research by Stephenson (BU 1998 to present) who has focused on developing new techniques to produce and render higher quality 3D images for feature film production. The techniques were collectively published in P1, made up of presentations at academic and commercial forums and journal publications (P2–7).

The main techniques emerging from the research are as follows:

- Anti-aliased noise to reduce artefacts when rendering rough or organic surfaces (P4).
- Vector texturing to allow vector artwork to be directly used within the 3D rendering process (P5).
- File compression techniques to significantly reduce file size without compromising quality (P6).
- Use of volumetric point clouds (P7) for rendering volumetric effects such as smoke.
- Motion blur (P2&P3).

The improved technique for producing motion blur was first presented in 2005 at the SIGGRAPH conference (P3).

It was later published in more detail in the Journal of Graphics Tools (P2). The research improved computer graphic representations of objects moving at speed.

A real camera records an image over a period of time, which leads to a blurring. Previously, software rendering systems captured a scene at a single instant and the lack of blurring appeared unnatural. Early motion blur techniques reflected the camera capturing light over a period of time, but failed to account for the fact that the shutter itself is a physical device which takes time to open and close. This approach was used without significant modification for over 20 years.

The publication of Stephenson's techniques in 2005 and 2007 marked a profound shift in practice for the industry. By incorporating the "slow" physical movement of a real shutter into computer graphics rendering software, Stephenson produced images that were much more closely matched to those of a real camera. In addition to being more physically faithful to a real camera the new

technique produces better images. The approach is aesthetically better and improvements can be clearly seen in the images. Mathematical analysis of the approach using sampling theory also shows the results are theoretically better.

Traditional motion blur methods check the position of each moving object at regular time intervals while the shutter is open. The new technique can easily be integrated into existing software by adjusting the times at which the object's position is tested. According to a specific mapping, the effect of a low efficiency shutter can be simulated. This re-mapping of sample times can be done very quickly, in comparison to the time taken to actually test an object's position. This means there are no measurable effects on render times. The technique is simple to implement, with increased creative control and image quality.

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

P1. Stephenson, I. (ed.) (2003). *Production Rendering, Design and Implementation*. Springer. ISBN: 978-185-233821-3

P2. Stephenson, I. (2007). Improving Motion Blur: Shutter Efficiency and Temporal Sampling. *Journal of Graphic Tools*, 12(1), 9–15. DOI: 10.1080/2151237X.2007.10129235.

SIGGRAPH

SIGGRAPH originally stood for Special Interest Group on Computer Graphics and Interactive Techniques when it was first established 40 years ago. It has now progressed significantly from a 'group' to an annual conference attracting between 20,000 and 30,000 technical and creative professionals from around the world. SIGGRAPH is widely recognized as the most prestigious forum for the publication of computer graphics research and is the most significant route for knowledge transfer between academia and the computer graphics profession.

P3. Stephenson, I. (2005). Shutter efficiency and temporal sampling. In: *International Conference on Computer Graphics and Interactive Techniques. ACM SIGGRAPH 2005 Sketches.* SESSION: Cinematography, 31 July–4 August 2005, Los Angeles, California. Article 101. DOI: 10.1145/1187112.1187234. Available from: http://dl.acm.org/citation.cfm?doid=1187112.1187234 [accessed 21 November 2013].

P4. Stephenson, I. (2001). Anti-Aliasing Perlin Noise. In: *International Conference on Computer Graphics and Interactive Techniques. ACM SIGGRAPH 2001 Sketches.* Available from: http://www.docstoc.com/docs/20199674/AntiAliasing-Perlin-Noise-Presented-at-Siggraph-2001 [accessed 21 November 2013].

P5. Haddon, J. and Stephenson, I. (2001). Vector Texturing. In: *International Conference on Computer Graphics and Interactive Techniques. ACM SIGGRAPH 2001 Sketches*.

Pixar User Group

This is an annual event organized by Pixar to coincide with the SIGGRAPH conference, attended by RenderMan users from major effects and animation studios. Users are invited to submit novel techniques and a small number are invited to present each year.

P6. Stephenson, I. (2002). *Compressing RIB files using DIFF*. Pixar User Group, July 2002, San Anatonio, Texas. http://dctsystems.co.uk/Text/diffRibs.pdf.

P7. Stephenson, I. (2003). *Rendering Smoke With Particle Maps*. Pixar User Group. August 2003, San Diego, California. Available from: http://dctsystems.co.uk/RenderMan/smoke.html [accessed 21 November 2013].

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

Stephenson's work has had a range of impacts on the industry. The publicly released source code for the anti-aliased noise research has been used at a number of studios and led to commercial rendering systems introducing their own variants (P3); vector texturing techniques allowed 2D vector artwork to be directly applied to 3D surfaces, which was implemented by Pixar in 2011 (P4); file compression techniques were used at Core Studios, Toronto to significantly reduce their disk space usage (P5).

The most significant impact though is that of Stephenson's motion blur research. The NCCA made the full implementation details publically available in an 'open source' format, with the intention that the approach could be widely adopted.

Following the SIGGRAPH 2005 presentation, Stephenson entered discussions with Pixar about his new techniques for motion blur. The Vice President of PRMan Products and a number of software developers were present. In 2007, Pixar implemented "Slow Shutter Opening/Timing" in their Photorealistic RenderMan (PRMan) Softwarewith the first films to use the technique emerging in 2008. The shutter opening controls were announced as a "Major New Feature" of PRMan 13 (R2).

In an email to BU, dated 27/07/2011, the Business Director for PRMan at Pixar said: "The Shutter Opening feature in Pixar's RenderMan software derived significant inspiration from the SIGGRAPH 2005 Sketch and JGT *[Journal of Graphic Tools]* 07 paper on Motion Blur authored by Ian Stephenson of Bournemouth University." He concludes: "The influence of this work on the development of the Shutter Opening Feature is fully acknowledged by Pixar Animation Studios'' (R3).

PRMan is used to produce all of Pixar's films as well as being commercially sold to other animation and digital effects production companies. Though motion blur is only one aspect of the highly complex techniques used for rendering, attention to detail at this level is what distinguishes high end commercial systems such as PRMan. Pixar's promotional material for their PRMan software specifically highlights the improved Motion Blur as one of its key features, describing shutter timing as "an innovative creative control for artistically sculpting the fall-off of blur" (R4&R5).

Pixar

The first Pixar animation to make use of Shutter Opening was in production of the short film, Presto, released in 2008. Director, Doug Sweetland considered that appropriate motion blur was essential for the story and was very specific about the type of effect he wanted. Shutter opening was the feature that made the film possible. He describes the new approach as "critical [for creating the] specific look", providing "creative control [and allowing the] creative vision to be realised" (R4).

Presto was used in the opening for the animated film Wall-E in 3,992 theatres in the US alone. Wall-E's worldwide gross was in the region of $521,311,860 (R6). Presto itself was nominated for an Academy Award and an Annie for Best Short film. In Internet Movie Database's (IMDb) list of best short films of all time, Presto received the highest rating (R7).

Following the success of the technique in Presto, Pixar began producing Cars 2, which was released in 2011. Motion Blur was used extensively in the film, which was more dependent on high speed action than any previous Pixar film. Cars 2 has a worldwide gross of $559,852,396 (R8).

Wider Influence

Pixar are an important software developer within the film industry (R4) and their software has been used by 49 out of the last 53 nominees for Visual Effects Academy Award. They sell their PRMan rendering software to most of the major digital effects studios. The extensive reach of the software is evident through their international clients, which include Digital Domain, USA; Weta Digital, New Zealand; Moving Picture Company (MPC), USA and Canada; Industrial Light and Magic (ILM) UK; Framestore (UK and USA), Cinesite, UK and Double Negative, UK among others. PRman currently

costs $2000 per copy, plus $600 annual maintenance. Studios such as these require thousands of copies each; generating significant revenue for Pixar.

Through its inclusion within PRMan, the Shutter Timing technique is now part of the software used on virtually every major feature film production including (in 2012 alone): The Avengers, Bourne Legacy, Brave, The Dark Night, The Hobbit, Jon Carter, Life of Pi, Men in Black 3, Prometheus, Ted, Total Recall and Skyfall (R9).

Though motion blur is a tiny part of these projects, the films alone generated billions of dollars in revenue and were viewed by hundreds of millions of people. Artists working on them recognise the importance of small details and, although the average audience member may not be able to explicitly identify them, they contribute significantly to the viewing experience. This in turn contributes to the global animation industry worth $207 US billion.

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

R1. *Global Animation Industry: Strategies, Trends and Opportunities Report 2013.* Research and markets value of animation industry in 2012. Available from http://www.researchandmarkets.com/reports/2568836/global_animation_industry_strategies_trends_and

R2. PhotoRealistic RenderMan 13.0 release notes. Available from: http://renderman.pixar.com/resources/current/rps/rnotes-13.0.html.

R3. Email from Business Director of RenderMan, Pixar Animation Studios, 27 July 2011. Available on request.

R4. Renderman product information (available on request).

R5. RenderMan motion blur and depth of field: http://renderman.pixar.com/view/motion-blur-and-depth-of-field.

R6. Financial information from Wall-E, Box Office Mojo. Available from: http://www.boxofficemojo.com/movies/?id=wall-e.htm.

R7. IMDb (2011) Best Short Films Ever. Available from: http://www.imdb.com/list/hobeL74d0rM/.

R8. Financial information from Cars 2, Box Office Mojo. Available from: http://www.boxofficemojo.com/movies/?id=cars2.htm.

R9. RenderMan, The Industry Standard: http://renderman.pixar.com/view/movies-and-awards.