

Impact case study (REF3b)

<p>Institution: University of Liverpool</p>
<p>Unit of Assessment: 10 – Mathematical Sciences</p>
<p>Title of case study: Applications of Singularity Theory and 3D Modelling in Arts and Retail</p>
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>Professor Peter Giblin (Department of Mathematical Sciences at the University of Liverpool), together with collaborators, used methods from singularity theory to develop an approach for recovering 3-d information from 2-d images, such as photos. In the past decade, these have been implemented and built upon by software engineers, leading to significant cultural, economic and societal impacts. These include the creation of an innovative 25m high sculpture of the human body in the Netherlands by the sculptor Antony Gormley and the virtual modelling of clothing on online clothing websites such as Tesco's (Virtual Changing Room by Tesco/F&F). These have reached thousands of consumers worldwide and represent a significant commercial success for the company which developed the software.</p> <p>2. Underpinning research (indicative maximum 500 words)</p> <p>The research underpinning this impact was undertaken by Professor Peter Giblin, working in the Singularity Theory Group at the Department of Pure Mathematics, now part of the Department of Mathematical Sciences. Professor Giblin worked on the mathematical foundations of Computer Vision, that is, the recovery of 3-dimensional information about the world from 2-dimensional images, perhaps from several viewpoints or from a moving (calibrated) camera whose positions in space may not be known. Specifically, the impact is underpinned by research undertaken from 1995-2000, mainly in collaboration with Cipolla (Cambridge) and Åström (Lund, Sweden), on using 2-d images to recover an arbitrary camera motion and the geometry of a surface.</p> <p>One of the key ingredients of recovery, or reconstruction, is the use of 'apparent contours', also called 'profiles', which are similar to silhouettes of surfaces. There is a corresponding idea for the apparent contour from a point of 3-space, which more precisely models views of an object from a stationary, or moving camera. Prior to the research described here, contours were discussed by Giblin and Weiss, and by A. Blake and R. Cipolla, in the context of reconstructing a surface given the camera motion.</p> <p>An important development came through adding the ingredient of 'frontier points', first investigated theoretically in the PhD thesis of Giblin's student Jeanette Rycroft (Liverpool 1992). A special case of circular motion was worked out in detail [3.1] by Giblin, Rycroft and F.Pollick (the latter working on the psychology of vision). An even more remarkable idea was that by using suitable optimizing techniques an arbitrary camera motion and the geometry of the surface, could be recovered from measurements of apparent contours and frontier points. This was investigated in research (1995-1999) between Giblin, R.Cipolla (by then in the Cambridge Engineering Department) and K. Åström (Lund, Sweden), the main article being published in 1999 [3.2]. Much of the theory was also described, with extensive background material, in the book by Cipolla and Giblin [3.3], which has 204 citations according to <i>Google Scholar</i>.</p> <p>As is often the case in mathematics, the impact of this research was not direct, but rather filtered through further work in software engineering. The ideas introduced were extended and made highly practical by several of Cipolla's PhD students and postdoctoral workers. (Giblin continued to act as external examiner on these topics in Cambridge and in Lund, but his work has now turned elsewhere.) Publications from Cipolla's group continue to refer to the fundamental mathematical work (especially Ref.[3.3]).</p> <p>3. References to the research (indicative maximum of six references)</p>
<p>[3.1] P.J.Giblin, F.E.Pollick and J.E.Rycroft, 'Recovery of an unknown axis of rotation from the profiles of a rotating surface', <i>J.Optical Soc. America</i> 11A (1994), 1976--1984, DOI:</p>

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10.1364/JOSAA.11.001976.

[3.2] K. Åström, R.Cipolla and P.J.Giblin, 'Generalised epipolar constraints', International J. Computer Vision 33 (1999) 51—72, DOI: **10.1023/A:1008113231241**. This is an expanded version, with more detail of the methods and results, of the article with the same name in Proc. European Conference on Computer Vision (ECCV) 1996, Lecture Notes in Computer Science 1065, Springer-Verlag, 97--108.

[3.3] R.Cipolla and P.J.Giblin, Visual Motion of curves and surfaces, viii + 184pp. Cambridge University Press, 2000.

Early results were published in [3.4] R.Cipolla, K. Åström and P.J.Giblin, 'Motion from the frontier of curved surfaces', Proc. Int. Conf. on Computer Vision (ICCV) June 1995 (IEEE Computer Society Press), pp. 269--275.

The research is published in leading international journals devoted to (often theoretical) computer vision. It has been well-cited, with [3.1] accruing 19 citations and [3.2] 14 citations as at September 2013. According to the Web of Science, the Journal of the Optical Society of America A has an Impact Factor of 1.67 and an Article Influence Index of 0.62 and is ranked 30th out of 80 journals on Optics; the International Journal of Computer Vision has an Impact Factor of 3.62 and an Article Influence Index of 3.01 and is ranked 9th out of 115 journals on Computer Science: Artificial Intelligence.

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

The impacts described here were developed by Professor Roberto Cipolla, based on the fundamental research with Professor Giblin described earlier. As Prof. Cipolla states in a letter [5.1], "*this work with Giblin and Astrom laid the essential groundwork for later developments by myself and my students and other collaborators, leading to important practical applications with significant external impact, such as those to sculpture (Anthony Gormley) and online retailing (Metail)*".

Applications in Sculpture.

Renowned sculptor Antony Gormley (creator of the "Angel of the North" in Gateshead and "Another Place" in Crosby) designed and built a 25-metre-high statue of a crouching human body, entitled "Exposure", which was unveiled in 2010 [5.3] in Lelystad in the Netherlands. The statue is built from interlocking pylon-like structures. This was achieved using software developed by Professor Cipolla at Cambridge, based on the fundamental research on singularity theory described above, carried out with Peter Giblin and published in joint work. This allowed 3-dimensional models to be reconstructed from a small number of ordinary camera images, in this case from 2-dimensional photographs of a cast of the artist's body. According to Gormley [5.4], this software is "unique in the world: it's extraordinary to get a fully rotational model from a standard single-lens digital camera".

The sculpture "Exposure" has been the subject of international news coverage [5.3], and is now an important landmark on the coast of the Netherlands. The impact here is cultural, since this work of art would not exist without the software developed from research completed in our UoA, and the public, especially in the Netherlands, have benefitted from this thought-provoking and impressive work.

Applications in Retail.

Metail is a company, founded in 2008 [5.5] and based in London and Cambridge, that offers "virtual fitting rooms". It now has 40 employees. The website allows users to easily generate a 3-dimensional personal body model to see how clothes would fit them online, prior to purchase. Shoppers are able to visualize themselves wearing complete outfits. The company's founder and CEO, Tom Adeyoola, first explored the possibilities of computer vision in the context of card

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recognition for on-line gaming. An internet search led to Roberto Cipolla and a personal contact with him. Tom was particularly impressed by the current preparations for Gormley's "Exposure" sculpture. Subsequently an ex-PhD student of Cipolla's was commissioned for the project of developing software for the virtual fitting room, based on the underpinning joint research with Peter Giblin on singularity theory described above.

Metail has raised over £4m in investment, filed patents and won a £100k grant from the Government's Technology Strategy Board in 2012 and a further £250k grant in August 2013. Metail launched to the public with its first trial commercial partner, Tesco, in February 2012 [5.6]. The trial was a success and went on to win an internal Tesco award for "Best on-line innovation" (voted for by the CEO Phil Clarke and the executive team). At the end of September 2012 Metail launched commercially on Tesco's main website, opening the "F&F Virtual Fitting Room". This website enable Tesco customers to try clothing online before they buy. The website is run in association with Facebook and the Home Page says "The F&F Virtual Fitting Room has been so successful on Facebook that we have made it part of our main website!". Subsequently Metail has launched with the clothing retailer Warehouse, and also with Zalando Germany (Germany's fastest growing clothing retailer), and the UK's largest on-line retailer, Shop Direct. Metail went on to launch their first live show TV experience 'Take over the Makeover' with ITV's programme "This Morning" in December 2012; this feature has been running monthly since March 2013. They launched their second international client of Dafiti in Brazil in February. Metail is currently generating around £70k per month in revenue and in March 2013 registered 80,000 users on their website. Over 300,000 people have created "MeModels" using their websites since February 2012. The impact here has therefore been economic, since Metail owes its existence and current success to the software developed from our research; and societal, since a large number of consumers in several countries have been enabled to "virtually" try on clothing before purchasing online. The CEO of Metail can confirm these details of company performance [5.7].

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

[5.1] Collaborating Professor from University of Cambridge, has provided a statement of support to corroborate the connection between the theoretical work with Peter Giblin and the impacts described above.

[5.2] [Publications](#) from Cipolla's group directly related to the impact, such as continue to refer to the fundamental mathematical work, establishing its foundational nature for the impact.

[5.3] [A report on Antony Gormley's sculpture](#), including a description of Prof. Cipolla's involvement, Archived at: <http://www.webcitation.org/69XxyH01M>
Other coverage: <http://www.mymodernmet.com/profiles/blogs/antony-gormley-exposure>

[5.4] Gormley quote, emphasising the critical role of the software based on our singularity research; in an article at: http://www.eng.cam.ac.uk/news/stories/2011/Antony_Gormley/

[5.5] [A description of Metail](#), including their connection to Professor Cipolla. Archived at <http://www.webcitation.org/69Xy7Vz2H>).

[5.6] The announcement of the opening of the F&F online fitting room based on Metail software can be found at <http://internetretailing.net/2012/03/tesco-launches-virtual-ff-fitting-room> and a "You-Tube" video showing the operation of the online fitting room can be viewed at <http://www.youtube.com/watch?v=UhYlvCROhck>

[5.7] The CEO of Metail can be contacted to corroborate company performance and impact of the software on the formation and development of the business.