Institution: University College London

Unit of Assessment: 11 – Computer Science and Informatics

Title of case study: 3D body scanning in clothing manufacturing and retail, and healthcare

1. Summary of the impact

UCL's pioneering use of 3D body surface scanning and national anthropometric surveys has had impact in the fashion industry and healthcare. In 2008, a UCL spinout, Sizemic, was founded to sell clothing size charts and fit mannequins based on the UK survey data, helping manufacturers and retailers improve the fit of their clothing, and reduce their product development times and costs. Sizemic now has 10 employees and a turnover of £1m. The research also led to other national sizing surveys, including in Germany (2008/9), Thailand (2009/10) and Mexico (2010), with results used for product development. In 2009, UCL built a prototype 3D-healthcare system for GPs and established a company, ShapeDynamics, to support the platform. The software is being tested at a private healthcare practice in London. Another UCL spinout, Bodymetrics, has commercialised body scanners for use as a clothes-fitting aid in stores.

2. Underpinning research

Between 1995 and 1998, Professor Philip Treleaven and his research group at UCL developed the first size-extraction software for the Hamamatsu 3D scanner. His research team was one of the first groups to develop software for extracting linear measurements from a point cloud. This involved taking the point cloud, cleaning the data of outliers, identifying body landmarks, and then calculating linear measurements related to the body landmark (e.g. chest circumference).

In the late 1990s, Treleaven realised the potential of these scanners for conducting national anthropometrics surveys. However, whole body scanners are 3D shape capture devices rather than devices for just capturing linear 'tape measure' measurements, so to realise their full potential, three areas of research were required - (a) software engineering (b) 3D body modelling and (c) 3D applications [1].

An initial challenge was in software engineering, as in order to fully utilise the potential of 3D whole-body scanners for surveys and screening subjects, a comprehensive data management infrastructure was required to automate registration, manage the measurement of subjects, store the body data, protect sensitive body data, and analyse the anthropometrics data.

From 2000 to 2008, Treleaven and his team worked with the US scanner company TC2 to develop pioneering size-extraction software. A benchmarking process required the scanning of a calibration mannequin, a range of adults and children of different ethnic origins, plus a range of underwear materials. The work led to SizeUK, Britain's first National Sizing Survey [1, 2] since the 1950s. Between 2001 and 2002, measurements were taken from more than 11,000 people across the UK using TC2 body scanners. Volunteers were chosen across three national regions to represent both genders, across seven different age groups from 16 years to 95 years, taking into account ethnicity and socio-economic factors. The software required Treleaven to develop advanced image processing to identify body landmarks (e.g. chest, waist, hips) and then extract linear or girth measurements. It was refined for later use in SizeUSA and other national surveys.

Treleaven's UCL collaborator, Professor Bernard Buxton, conducted pioneering research into 3D body modelling for analysing 3D shape and calculating average bodies based on shape [3, 4]. This was developed specifically to generate 3D average body shapes from subsets of the SizeUK data and show the variation in shape across the subset. This involved the application of a robust and efficient iterative closest point (ICP) algorithm for fitting a deformable 3D human torso model to noisy data [3, 4, 5]. This led to further work into 3D pattern development for custom and ready-to-wear clothing.

UCL co-ordinated the data analytics used for size chart and pattern block development with retailers including Marks & Spencer, Tesco, Arcadia and Next. All clothing sold by major retailers is

based on their company size charts, which are specific to a given demographic customer profile. The computer science innovation was to use 3D body modelling that worked using 3D shape data for averaging, rather than the traditional method of using linear measurements to calculate average body sizes and group cohorts for size ranges.

Since 2008, Treleaven's research has focused on the development of software for clothing technology, such as customised 3D virtual and physical fit mannequins based on Buxton's 3D shape analysis tools. The 3D body modelling research was used to cluster subjects based on their shape rather than linear measurements. This data was then used to produce unique and highly accurate virtual and physical mannequins. The 3D body modelling research allows an 'average' virtual mannequin of a specific size for a given cohort of subjects to be produced, which is then used to produce a range of virtual mannequins (e.g. for UK women's sizes 6 to 28). The physical mannequins are built according to data from SizeUK and SizeGermany, and are manufactured in China, with the 3D body modelling research continuing to be pursued at UCL.

In healthcare, Treleavan has worked with Professor Jonathan Wells at UCL's Institute of Child Health on the analysis of SizeUK, SizeUSA and SizeTHAILAND for obesity. This involved 3D body modelling research [6], demonstrating the limitations of BMI and the 'velocity' of obesity in children. The group has built anthropometrics software and analytics for doctors' surgeries.

The main researchers were: Professor Philip Treleaven, Professor of Computer Science at UCL since 1986, Professor Bernard Buxton, Professor of Information Processing Systems from 1994 and then Dean of Engineering till 2009, and Dr. Anthony Ruto (consultant, 2009-2013).

3. References to the research

[1] P. Treleaven, Sizing Us Up, IEEE Spectrum, vol. 41, pp28-31, 2004. http://doi.org/db9tqw

[2] J. Bougourd and P. Treleaven, UK National Sizing Survey - SizeUK, Proceedings of the International Conference on 3D Body Scanning Technologies, Lugano, Switzerland, 19-20 October 2010. http://www.3dbodyscanning.org/2010/docs/3dbody_proceedings.pdf

[3] A. Ruto, M. Lee, B. Buxton, Comparing Principal and Independent Modes of Variation in 3D Human Torso Shape Using PCA and ICA. Presented at ICArn 2006, ICA Research Network International Workshop, Liverpool, UK, 18 - 19 September 2006. http://www0.cs.ucl.ac.uk/staff/a.ruto/papers/arutoICArn2006Paper.pdf

[4] A. Ruto, B. Buxton, Application of a Robust and Efficient ICP Algorithm for Fitting a Deformable 3D Human Torso Model to Noisy Data, DICTA 2005, Digital Image Computing: Techniques and Applications, Cairns, Australia, 6 - 8 December 2005. http://doi.org/fv5495

[5] A. Ruto, B. Buxton, I. Mirkin, C. Goonatilake, Secure Online 3D Human Body Database, Proceedings of Scanning 2001, Paris, May 2001. Available on request.

[6] J. C. K. Wells, A. Ruto, P. Treleaven, Whole-body three-dimensional photonic scanning: a new technique for obesity research and clinical practice. International Journal of Obesity, 2008, 32, 232-238. http://doi.org/djfs2s

References [1], [3] and [4] best demonstrate the quality of the research.

Research funding: SizeUK was co-funded by a £2 million DTI Grant (Foresight Link Award 62: 3D Electronic Commerce) and by 14 major UK retailers, who provided in-kind funding of £2 million.

4. Details of the impact

UCL's research pioneered 3D body-surface scanning and its application to the clothing industry. Since 2008, sizing surveys have been conducted in numerous countries, leading to improvements in clothing manufacture and efficiency in the global retail industry overall. In addition the research has now also had impact in healthcare by supporting work on combating obesity and related diseases such as diabetes. Further success is evidenced by the growth of UCL spinout companies.

Sizing surveys: Since 2008, countries around the world, including Germany, Thailand, Mexico

and Italy (2012) [a] have conducted large-scale sizing surveys, based on the earlier UK National Sizing Survey. UCL either managed or advised on these national surveys. In Germany, where the survey was carried out in 2008, the results have been used to update German size charts, produce virtual avatars, and by Sizemic to create a range of SizeGERMANY fit mannequins [b].

In Thailand, the anthropometrics data generated by the 2009 national size survey has been used to assist the Thai clothing industry. The scan data collected in SizeTHAILAND was used to construct the first-ever standard Thai body size chart. The chart has now been used by clothing manufacturers in Thailand to design and produce clothes that better fit the Thai population. The director of SizeTHAILAND confirms that "according to feedback from leading uniform clothing manufacturers who have adopted the SizeTHAILAND sizing system, there has been an approximately 35% reduction in overall clothing alterations." [c]

Impact on retail and manufacturing: The results of the SizeUK survey have had a significant impact on manufacturing. Analysing the SizeUK anthropometrics data and related analytics, UCL and its partners developed company/brand specific size charts for over 25 UK retailers based on the retailer's/brand's specific demographic customer profile. This work started in 2005 but has been ongoing through 2008-2013 as companies redo their size charts and new companies purchase the SizeUK data.

Since 2008, manufacturers have particularly benefited from the development and use of SizeUK and SizeGERMANY fit mannequins. Fit mannequins are used in the clothing industry for product development and quality assurance. The work by Buxton, described above, has underpinned Sizemic's commercialisation of fit mannequins, developed from 3D SizeUK shape data. This process ensures the mannequins are realistic and have accurate body shapes, truly representative of their age group and target customer profile.

Sizemic offers both customised mannequins and a range of specially developed generic mannequins, available in a variety of sizes and shapes representing different age groups for both genders. In Germany, the range consists of 13 standard-sized fashion mannequins for men, women and children [b]. This enables retailers to establish the optimum body shape for their target market and standardise this across their supply chain, ensuring that all of a company's suppliers are developing and fitting product on the same body size and shape. Sizemic's managing director lists feedback from the company's clients on the use of fit mannequins: "greater accuracy and consistency of fit as all suppliers are fitting and developing product on exactly the same body size and shape (size and shape standard); excellent QA [quality assurance] communication tool; reduction in returns for fit and sizing; reduction in production development time and costs." [d]

Use of these mannequins speeds up the product development lifecycle, as samples no longer need to be shipped back and forth between suppliers in Asia and retailers in Europe and America [d]. This helps to underpin 'fast fashion' by reducing lead times, reducing the need for sampling and ultimately reducing air-freight costs by ensuring the correct products reach the correct retailers and consumers. Improved garment fit and development efficiency enhances the suppliers' relationship with their retail clients, ensuring benefits on both sides of the transaction as well. The increased customer satisfaction and loyalty leads to increased sales and therefore profit. This is particularly true given the growth of internet shopping, with retailers taking on the burden of supplying customers with multiple sizes as they are unsure what size will fit.

Prior to the use of fit mannequins, it would typically take four to five iterations of a sample before a retailer could finally approve it. This has now been reduced to one or possibly two iterations, resulting in at least a 50% reduction in sample making, shipping and fit model costs. It also speeds up the product development time by at least 25%, which is critical for the 'fast fashion' retailers that make up Sizemic's customers, including Tesco, New Look, Topshop, Miss Selfridge, Sainsbury's and Boden [d].

Another UCL spinout company, Bodymetrics, originally set up in 2000, produces body scanners for use in clothing retail. At Selfridges department store in London and Bloomingdales stores on the

west coast of America, Bodymetrics pods scan customers to provide made-to-measure jeans and identify which brand will most suit individual customers; as of 2012, the pod accounted for 20% of all premium jeans sales at Selfridges, where it has been in use since 2009 [e] and where it grosses $5,000 annually per square foot of retail space [f]. In 2011, another pod was installed in a high-street fast-fashion store in London [g]. The retailer, New Look, also uses Bodymetrics scanning technology in-house to ensure uniformity of size for garments manufactured in factories across the world [g].

Adoption of new technology in healthcare: Treleaven and his collaborators have developed a 3D healthcare system for GP practices that analyses and comments upon a patient's 3D anthropometrics, comparing the patient's scan to the SizeUK data. A patient is scanned and the GP then compares the patient's anthropometrics data with the SizeUK database to identify any deviation of the patient from national norms, such as over or underweight and the shape of the stomach which is an indicator of the propensity for the onset of Type II Diabetes. A company, ShapeDynamics, was established in 2010 to support the software. Since 2011, the system has been undergoing trials at a large private GP practice in the City of London. To date, 240 patients have been scanned. [h]

Creation of spinout companies: The spread of national sizing surveys around the world has had an economic benefit for Sizemic. Set up in 2008 as a UCL spinout, the company now has 10 employees, with offices in London and Hong Kong, and a turnover of £1m [d]. Since 2008, Bodymetrics has expanded to 10 employees and started business in the United States [i, e].

5. Sources to corroborate the impact

[a] Confirmation of the date of the SizeMEXICO survey in 2010-2011 http://www.tc2.com/history.html; SizeITALY: http://www.sizeitaly.it

[b] SizeGermany fit mannequins unveiled, 10 June 2013, http://www.just-style.com/news/sizegermany-fit-mannequins-unveiled_id118109.aspx

[c] A letter from the director of SizeTHAILAND corroborates that the survey benefited clothing manufacturers in Thailand, the 35% reduction in clothing alterations, and the link to UCL's work. Available on request.

[d] Letter from the managing director at Sizemic Limited corroborates the information relating to Sizemic, e.g. investment funding, employment figures, turnover and customers. It also confirms the reduction in product development time through the use of fit mannequins, and details the positive customer feedback Sizemic has received from its customers. Available on request.

[e] For corroboration of the use of Bodymetrics scanners in the United States and that the pod accounts for 20% of Selfridges' jeans sales, see: http://www.prnewswire.com/news-releases/bloomingdales-and-bodymetrics-open-body-sizing-pod-in-silicon-valley-165557926.html; Its use in scanning for made-to-measure jeans: http://www.ilovejeans.com/the-denim-detective/

[f] Bodymetrics pod grosses $5,000 per square foot of retail space: http://www.bodymetrics.com/pr/oct2011.php

[g] New Look's use of Bodymetrics scanners in store and for manufacturing consistency, see Daily Mail, 18 October 2011, http://dailym.ai/HRFDjd

[h] A letter from the Director of Shape Dynamics confirms the establishment of the company, the benefits of the system and the number of patients scanned so far. Available on request. See also http://www.shapedynamics.com.

[i] Bodymetrics' CEO can corroborate the company's growth during the REF impact period. Contact details provided separately.