Institution: University of Leeds

Unit of Assessment: UoA 11(Computer Science and Informatics)

Title of case study:

Commercial software for modelling and visualising manufacturing variation in automotive products – users save estimated £25 million

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

Researchers from this UoA developed 3D modelling techniques and virtual visualisation software to help car-makers address potential imperfections (gaps between panels, misalignments, etc) that arise during vehicle assembly, even when all part dimensions are manufactured to within their tolerance range. The University of Leeds spun out Icona Solutions in 2003 to develop and exploit this intellectual property. Icona's *Aesthetica* software was launched in 2006, and since 2008 it has been licensed by over 20 automotive companies in 10 countries. The software has contributed to improvements in the design and manufacture of around 70 different vehicle lines, reaching over 40 million consumers, and saving car-makers approximately £25 million in efficiency and cost savings (including reduced scrap and rectification costs). Icona's turnover since 2008 is well over £1 million.

2. Underpinning research (indicative maximum 500 words)

Background

In 1996, the Rover Car Company approached the University of Leeds for help with a quality control problem. The company was concerned that after assembly a number of manufactured cars failed to match the visual appeal of the original CAD design, despite all components being manufactured to within their specified tolerances. These cars had to be scrapped or rectified leading to waste and increased production costs.

This problem arises because CAD packages show what a perfectly constructed car will look like. However, its actual construction is always "within tolerance". For example, two adjoining bodywork panels will have lengths that fall within a tolerance range, but, if each panel is at the minimum range, an unsightly gap might appear between them on the car.

Professor Peter Dew assembled and led an EPSRC-funded consortium to research and develop solutions to these problems highlighted by Rover. This consortium [*Visualisation of the Impact of Tolerance ALlocation in automotive design (**VITAL**)*, GR/M12094/01 (01/10/1998 to 31/12/2001), £214,769 from EPSRC plus industrial contributions, PI Professor Peter Dew] included Neal Juster (Department of Design and Engineering Management, University of Strathclyde) together with Rover, SGI and Rover's Tier 1 supplier, Magna, as industry partners.

Dew and John **Maxfield** (PDRA) were the key Leeds researchers involved in the project, leading the research and development into: modelling the effects of the manufacturing variation, representing these effects visually, and developing a software tool.

Primary underpinning research: the VITAL project

The Leeds research in VITAL built on **Dew**'s earlier work into interactive, constraint-based solid modelling [1], and upon **Dew** and **Maxfield's** prototype distributed virtual environment for interactive synchronous collaboration in engineering product and process design [2]. Specifically, as described in [3,4], the Leeds researchers explored new modelling approaches to capture the effects of manufacturing variation. They the then developed a prototype software tool for users to simulate and view an interactive 3D model, allowing them to visualise what would happen to the appearance, fit and finish of an assembled car when manufacturing variation (within user-supplied

tolerances) was introduced for specific parts or assembly processes.

The 3D modelling approach applied tolerances and component deformations directly to the 3D CAD geometry of component parts. These alterations to the 3D models could then be visualised in a photorealistic, real-time 3D virtual environment. The visualisation module provided accurate representations of how deformations, irregularities and misaligned components and assemblies would actually appear from any angle and in different lighting conditions.

Dew and **Maxfiel**d investigated the behaviour of the tolerance models used in the software (representing the deformation of components under prescribed conditions and their allowable manufacturing variations respectively); they also applied the models within an automotive design and manufacturing process [3]. Following further model enhancements, the researchers worked with the VITAL industrial partners to fully evaluate the research software prototype using an industrial case study of a glove box assembly within a typical automotive instrument panel that is composed of both rigid and flexible components [4].

Alongside this activity, VITAL's Strathclyde research team (led by Juster) worked with users, and potential users, to assess where the technology could best fit into the design and manufacturing process; Juster fed this information into the requirements for the Leeds software developers. Although Strathclyde's work was essential to the eventual successful exploitation of the software, the formation of Icona Solutions itself and the subsequent software product *Aesthetica* were based solely on the intellectual property generated by the University of Leeds' researchers.

Product development

Upon completion of the EPSRC research described above, the University of Leeds employed **Maxfield** to continue development of the software tool (with some financial support from SGI, whose visualisation modules were used) towards commercialisation. The spin out company Icona Solutions Ltd. was established in 2003 with the aid of start-up funding of £300,000 from the WhiteRose Seedcorn fund. This supported the company to develop the software interface, documentation and marketing and sales operations, through to the launch of *Aesthetica* in late 2006.

Key researchers

Professor Peter **Dew** [text removed for publication]

Dr John **Maxfield** [text removed for publication]

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

1. Fa, M; Fernando, T; Dew, PM, Direct 3D Manipulation Techniques for interactive constraint-based solid modelling. *Computer Graphics Forum*, **12**(3):237-248, 1993, DOI: 10.1111/1467-8659.1230237

2. Maxfield J; Fernando T; Dew PM. A distributed virtual environment for collaborative engineering. *Presence: Teleoperators and virtual environments*, **7**(3):241-261, 1998, DOI: 10.1162/105474698565695.

3. Juster NP; Maxfield J, Dew, Peter M; Taylor, Stephen; Fitchie, Martin; Ion, William J; Zhao, Jeff; Thompson, Martin, Predicting product aesthetic quality using virtual environments. *Trans of the ASME, Journal of Computing and Information Science in Engineering*, **1**(2):105-112, 2001, DOI: 10.1115/1.1387244.
This paper first appeared in the Proceedings of the International Conference on Engineering Design (ICED 01) 2001, with the authors subsequently invited to submit to the (fully refereed) international journal.

4. Maxfield, J. Dew, P. M. Zhao, J. Juster, N. Fitchie, M., A virtual environment for aesthetic quality assessment of flexible assemblies in the automotive design process. *SAE Technical Paper* 2002-01-0464, 2002, DOI: 10.4271/2002-01-0464.
   *This paper was selected to appear in the SAE Transactions (and re-published as SAE Transactions, **111**(5):209-217, 2002, ISSN 0096-736X, which "is an annual collection of the technical papers from that year which are best suited to be preserved in permanent literature" (quoting from http://www.sae.org/events/ads/transactions.htm)).*

Papers [3] and [4] best illustrate the quality of the underpinning research, as evidenced by their selection for re-publication (see notes above).

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

Consumer impact – better looking, higher quality vehicles

The look of a vehicle plays an important role in the purchasing decision. Customer feedback and announcements show that *Aesthetica* helps manufacturers to maintain consistency in the looks of their vehicles through better dimension control of parts and by redesigning, at an earlier stage, to avoid high imperfection rates [A]. Icona customers say that application of *Aesthetica* improves how the quality of products are perceived at all major phases of the digital product development process [B,C,D]. Ultimately, *Aesthetica* helps car-makers ensure that the final product assemblies are more visually appealing, matching the looks originally conceived by the designer and hence satisfying customers' expectations on perceived quality [E].

For example, GM Europe has used the software to refine the lines of the Opel/Vauxhall Insignia which contributed, in part, to the model winning European Car of the Year 2009 [E].

Commercial impact – Icona growth, exceeding £1 million sales, private buy-out

The company has approximately 30 existing customers, the vast majority in the automotive industry. Customers include: most western mass-market automotive original equipment manufacturers (OEMs) (e.g., Audi, Chrysler, Fiat, Ford, General Motors, Nissan, Renault and VW), many premium and sports car OEMs (e.g., Ferrari, Lotus, McLaren, JLR, Porsche and Bentley) and growing numbers of eastern automotive OEMs (e.g., Hyundai, Kia and Ssangyong (Korea), First Automotive, Great Wall, Qoros and SAIC (China) and Tata Motors (India)) [F].

Since the launch of the commercial *Aesthetica* product, Icona Solutions has grown steadily – with total sales of *Aesthetica* licences and technical support exceeding £1 million since 2008, and a current sales pipeline of over £3 million [F]. This is built upon a network of agents and resellers in every major territory around the world, including mainland Europe, USA, Brazil, Australia, China, India, South Korea and Japan.

On the basis of these achievements, in October 2013 Icona Solutions was acquired by the French-based multinational company OPTIS SA (www.optis-world.com). (The price paid by OPTIS for Icona Solutions is not public and OPTIS are not prepared to share this information with us.)

Commercial impact – £25 million savings to customers

Some Icona customers have been willing to disclose to Icona estimates of the financial benefits they receive from using *Aesthetica*. For example, BMW Mini achieved immediate cost savings of over US$100,000 per year using *Aesthetica* on an existing production vehicle through reduced scrap, less rectification (i.e., less work to rectify imperfections) and a significant reduction in the cost of labour [G]. Similarly, on individual new-vehicle programmes, Porsche used the software and identified savings of at least €250,000 [G]; Nissan estimates savings of US$875,000 due to reduced re-tooling, less building of physical models and faster product development [H].

Icona, and other customers [A], believe that these three examples are typical of cost savings in the

industry from use of its software: the value of *Aesthetica* to the automotive industry is therefore estimated at between £200,000 and £500,000 per product line. Taking Icona's estimate of approximately 70 different product lines benefiting from *Aesthetica* in the automotive industry [F] and assuming a conservative typical financial benefit of £350,000, *Aesthetica* has generated a total financial saving of the order of £25 million to Icona's customers in the impact period.

Indication of consumer reach

Aesthetica is used by around 20 companies [F] in the automotive industry and has provided input into the design and assembly of around 70 different vehicle lines [F]. It is therefore possible to undertake a crude estimate as to the number car buyers who have benefited from the improved looks and build quality realised by the use of *Aesthetica*.

The total 2012 car and light vehicle sales in the USA [I] and Europe [J] from Icona's largest OEM customers (Audi, Chrysler, Fiat, Ford, General Motors, Nissan, Renault and VW Group) were around six million in each market. Allowing for *Aesthetica* having influenced the final design of those vehicles sold since the start of 2010 (which is a conservative estimate), around 42 million car buyers in Europe and the USA alone will have benefited from the application of the *Aesthetica* software during the REF impact period.

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

A. Testimonial from Head of Concepts Department, Bentley Motors, November 2013.
B. Right Image, http://www.iconasolutions.com/News_Press/engineering.pdf (pp 49 – 51 in Engineering Magazine, September 2009).
C. FIAT Implementing aesthetica from Icona Solutions, http://www.pddnet.com/news-fiat-implementing-aesthetica-from-icona-solutions-082310/, 23rd August 2012, Accessed 3rd March 2013.
D. Great Wall Motor Company selects Icona software simulation of the perceived quality, http://tech.elecbuzz.com/great-wall-motor-company-selects-icona-software-simulation-of-the-perceived-quality/, 4th July, 2011, Accessed 3rd March 2013.
E. Aesthetica Speeds New Opel to Car of the Year, http://www.deskeng.com/articles/aaatmb.htm, January 3, 2010, Accessed 3rd March 2013.
F. Testimonial from Technical Director and Co-Founder, Icona Solutions Ltd, May 2013.
G. Presentation on Aesthetica provided by Technical Director and Co-Founder, Icona Solutions Ltd., March 2013.
H. http://www.plicatec.com/download/Icona_Heavy_Duty_and_Agritech_process_case_studies.pdf, Accessed 20th August 2012.
I. US Car Sales 2012 by Brand.
J. Europe Car Sales 2012 by Brand.