Institution: The University of Huddersfield

Unit of Assessment: 15 General Engineering

Title of case study: The Development of World Leading Surface Metrology Software

1. Summary of the impact

University of Huddersfield research into surface metrology, carried out as part of the EU-funded SURFSTAND project, has led to worldwide changes in manufacturing. Nine ISO standards related to measuring the surface roughness of parts have been developed as a result, influencing practices in sectors ranging from aerospace and automotive engineering to microelectronics and bio-implant production. Consequently, all quantitative 3D surface measurement carried out in the world now draws on the research. Instrument manufacturers and the National Physical Laboratory have also implemented the standards, while software developed as part of the research has been incorporated by a leading industrial partner, significantly enhancing the company's offering and market position.

2. Underpinning research

A manufactured product's surface micro-structure affects its performance, quality and service life. Although a surface might appear flat and smooth, measurement and characterisation can reveal a complex structure – often the result of factors involved in the manufacturing process. Research by the University of Huddersfield's Centre for Precision Technologies (CPT) has sought to achieve significant improvements in the way industry measures and understands surface roughness.

In 1998, a year after its work in characterising areal (3D) surface roughness and developing measurement instrumentation began, CPT coordinated an 11-partner EU Framework project, SURFSTAND. The principal aim was to develop mathematical analytical techniques for characterising the topography of engineering surfaces, with a view to the work forming the basis for a series of international standards. Liam Blunt (Professor of Surface Metrology; joined University of Huddersfield 1997) served as PI, and Xiang Jiang (Professor since 2003) was primary Research Fellow. The project's industrial partners, including VW, Volvo, SKF, DePuy, J&J and Taylor Hobson, provided case study data or acted as potential research exploitation partners.

The project led to findings relevant to a range of industry stakeholders, including the automotive, steel production and bio-implant manufacture sectors. It was demonstrated that characterising areal surface roughness delivered clear advantages in the understanding of surface functions in areas such as engine emissions (VW), sheet steel pressing (Volvo) and implant quality control (DePuy). Along with characterisation techniques, procedures for data filtering and instrument characterisation were also developed [1, 2, 3].

The research also resulted in the development of tools for the characterisation of surface topography. Largely developed at Huddersfield, these were assembled into an advanced piece of software, also known as SURFSTAND, using a component-based architecture in order to facilitate structured future development. SURFSTAND enabled multiple data formats to viewed, filtered and numerically characterised. Clear advances in the software allowed for characterisation of free-form geometry (a world first), wavelet filters for multi-scale analysis (a first in surface metrology), regression Gaussian filtering to remove underlying form error and surface pattern analysis.

After three years of work the SURFSTAND project's outcomes were reported to the relevant ISO and CEN standards committees. This led to Jiang and a second member of CPT, Paul Scott (Taylor Hobson Visiting Industrial Professor, 2001-2010; Professor of Computational Geometry, 2010-present), being drafted on to ISO committees to work on developing the documents into international standards.

The significance of the insights that emerged from the research was further highlighted in a major review of the discipline, published in two parts in 2007. Identifying the accurate measurement of surface texture as arguably the most critical factor in the performance of high-precision and nanoscale devices and components, Blunt, Xiang and Scott charted surface metrology's journey

from the fundamental concepts of the 1940s and 1950s to the robust and flexible approaches of the early 21st century, as typified by Huddersfield's own work [4, 5].

3. References to the research

1. *Advanced Techniques for the Assessment of Surface Topography* Ed. L. Blunt and X Jiang Kogan Page Science 2003 London. ISBN 9781903996119.
2. X.Q. Jiang, L. Blunt and K.J. Stout, "Development of a lifting wavelet representation for characterisation of surface topography", *The Proceedings of the Royal Society A* (2000) 456, 1-31. doi. 10.1098/rspa.2000.0613
3. L. Blunt X.Q. Jiang and K.J. Stout "Three dimensional measurement of the surface topography of ceramic and metallic orthopaedic joint prostheses" *Journal of Materials Science: Materials in Medicine*, pp235-246 11(2000). doi 10.1023/A:1008924511967
4. X Jiang, P. Scott, D. Whitehouse, L. Blunt "Paradigm Shifts in Surface Metrology, Part I: Historical Philosophy", *The Proceedings of the Royal Society A* 463 pp. 2049-2070, 2007.doi 10.1098/rspa.2007.1874
5. X Jiang, P. Scott, D. Whitehouse, L. Blunt "Paradigm Shifts in Surface Metrology, Part II: The Current shift", *The Proceedings of the Royal Society A* 463 pp. 2071-2099, 2007. doi. 10.1098/rspa.2007.1873

4. Details of the impact

CPT's research into surface metrology has significantly influenced practices throughout the manufacturing sector.

In order to facilitate knowledge exchange, demonstration versions of the software developed as part of the SURFSTAND project were distributed to all partners, among them world-leading metrology company Ametek Taylor Hobson. At the time the company, which is based in the UK and specialises in the supply of measurement systems to major industrial sectors, was in the process of upgrading its own software. After a period of negotiation Taylor Hobson concluded a formal research collaboration contract with CPT to exploit SURFSTAND within the company's own software offering, as supplied with its instruments. Subsequent work, beginning in 2009, focused on third-generation wavelets for the extraction of morphological features, enhanced surface visualisation and routines for robust Gaussian filtering. In 2011, as part of a larger collaboration that also involved PhD sponsorship, a licensing agreement to incorporate the latest advances into Taylor Hobson's software was signed. SURFSTAND has now been fully structured into a piece of component-based software that can be bolted on to the many different types of metrology instrumentation Taylor Hobson offers, and all of the company's software products use the basic knowledge developed from the project [a].

Taylor Hobson's sales have increased as a direct result of these advances, with presence in some markets doubling since the integration of SURFSTAND and its derivatives into the company's advanced instrumentation. The company is currently one of the leading metrology instrument suppliers to the manufacturing sector in China, with double-digit growth in sales year on year. Taylor Hobson's Technical Director has confirmed that SURFSTAND has "enabled us to maintain a competitive market position", particularly in the fields of optics (e.g. lenses for smartphone and DLR cameras) and bearing surfaces (e.g. those capable of delivering "green" low-friction performance for the automotive industry) [b].

In 2009 one of Taylor Hobson's leading research engineers took up a Chair at CPT. Conversely, two of the Research Fellows who worked on the software are now employees of Taylor Hobson, having been trained at an advanced level at CPT, and lead all software development in the company, thus facilitating further knowledge exchange. In 2012, in another illustration of the strength of CPT's collaboration with the company, Taylor Hobson sponsored a new Chair in Surface Metrology. The company's Technical Director has acknowledged the "fruitful" partnership and has credited the formative and continuing research with helping to provide "the necessary bedrock of research from which to build commercially viable industrial solutions in global markets"

[b].

CPT researchers remain active on ISO committees that promote the outcome of the SURFSTAND project and incorporate them into Geometrical Product Specification (GPS) standards, the most recent of which were published in 2012. This work involves the standardising of numerical parameters, data filtering, verification and specification rules and data formats. So far nine standards documents have been produced as a direct result of the SURFSTAND project (ISO 25178 – Areal Surface Texture), and the research has also contributed to 14 other standards (ISO 16610 – Filtration) [c, d, e].

As a result all companies that are ISO-compliant measure surfaces using the results of the SURFSTAND project. ISO-compliant measurement is essential in virtually all manufacturing sectors and is part of many quality systems, including Six sigma and ISO9000. SURFSTAND output can therefore be found in areas of manufacturing ranging from aerospace and automotive to microelectronics and bio-implant production. The relevant ISO Convenor has described SURFSTAND as “core” to the development of these standards, adding: “[They] are the means by which surface property measurement across the world is compliant and traceable... Consequently, they are key to all aspects of modern manufacturing.” [f]

In addition, all companies that supply industry with surface-measuring instrumentation must implement the results of the SURFSTAND project through compliance with ISO. One such supplier is French company Digital Surf, a major global player in the field, which uses CPT-authored ISO standards and algorithms across its entire product range [g]. The National Physical Laboratory (NPL) has also implemented the SURFSTAND results on its instrumentation and through the collaborative development of web-enabled software tools in the form of its SoftGauges – digital gauges that are hosted online to allow end-users to check the correctness of the surface metrology software provided by instrument vendors. Acknowledging SURFSTAND’s importance, the Principal Research Scientist at NPL’s Engineering Measurement Division has noted: “Without this fundamental research the SoftGauges project would not have been possible and the application of verified and compliant software in support of manufacturing would be hindered.” [h]

The SURFSTAND work, along with the international industry links and further research it engendered, was crucial to CPT being named one of the new EPSRC Centres for Innovative Manufacturing. Supported by £8m in funding, this identifies CPT as a national centre of excellence and innovation in advanced metrology. Business Secretary Vince Cable officially opened the Centre in October 2011 and remarked that it would “ensure Britain stays ahead of the game in precision technology”.

5. Sources to corroborate the impact

a. Taylor Hobson TALYMAP software, incorporating SURFSTAND
http://taylor-hobson.virtualsite.co.uk/talymap_software.htm

b. Advocacy from Technical Director, Taylor Hobson

c. Selected ISO standards document: Geometrical Product Specifications (GPS), Surface Texture Areal, Part 2: Terms, definitions and surface texture parameters
ISO 25178-2 2012

d. Selected ISO standards document: Geometrical Product Specifications (GPS), Filtration, Part 29: Linear Profile Filters: Spline Wavelets
ISO 16610-29 2006

e. Selected ISO standards document: Geometrical product specifications (GPS), Surface Texture Areal, Part 6: Classification of Methods for Measuring Surface Textures
ISO 25178-2 2012

f. Advocacy from Convenor, ISO/TC 213/WG16, International Standards Organisation

g. Advocacy from Chief Operating Officer, Digital Surf

h. Advocacy from Principal Research Scientist, Engineering Measurement Division, National Physical Laboratory