Institution: University of Birmingham

Unit of Assessment: UoA 11 – Computer Science and Informatics

Title of case study: SIAscopy (Spectrophotometric Intracutaneous Analysis) for rapid non-invasive quantification and assessment of skin histology in cancer and cosmetics

1. Summary of the impact

SIAscopy is an image analysis method using the physics of image formation. It non-invasively provides near-instant quantitative maps of the key histological components of the skin. The scientific underpinnings were developed by Prof. Claridge's group, patented, and commercialised via a spin-off company Astron Clinica. *SIAscopy* was incorporated into medical imaging products which improved accuracy of general practitioners in diagnosis of melanoma, a skin cancer, whilst delivering higher cost-effectiveness than best clinical practice. Developed primarily for cancer diagnosis, SIAscopy also found uses in the cosmetics industry. In 2011 the current IPR owner, MedX, estimated the US market opportunity for the technology to be around $1 Billion.

2. Underpinning research

Contextual information. All the research underpinning *SIAscopy* was carried out within the University of Birmingham through projects led by Professor Ela Claridge (Professor of Medical Image Analysis) in collaboration with clinicians (Birmingham, Cambridge) and a spinout company, *Astron Clinica*. This research led to the development of two imaging systems.

- *Contact SIAscopy*, where a hand-held probe is placed against the skin and calibrated images of high resolution are acquired. Subsequent computer analysis yields histological maps showing quantitative topographic maps of epidermal melanin, dermal melanin, haemoglobins and papillary dermis thickness. This method is used for diagnosis of individual skin lesions and shows high sensitivity and specificity.
- *Non-contact SIAscopy*, where images of an arbitrary field of view can be taken using a conventional digital camera. This method does not require either calibration or tissue contact. Computer analysis yields parametric maps of epidermal melanin, dermal melanin and haemoglobins. These are used for pre-screening of whole body areas ("mole mapping"). The method is tuned for high sensitivity; any suspicious moles can then be analysed in detail by *contact SIAscopy*.

Contact SIAscopy was developed as a part of a doctoral research programme (Cotton, 1994-1998) supervised by Prof. Claridge in clinical collaboration with a Specialist Registrar (Hall, Birmingham Children's Hospital). Subsequent research was funded by EPSRC (1999-2003); Mr Hall (then a Consultant Plastic Surgeon at the Addenbrookes Hospital, Cambridge) provided clinical consultation; Dr Moncrieff was a clinical RF on the project; *Cambridge Design Partnership* (who later employed Dr Cotton) were industrial partners. This research pioneered a novel and unique approach to the interpretation of skin images. The key insight was that using a physics-based model of image formation a cross-reference between pixel colours and quantitative histological parameters can be established [1]. Parametric maps derived from the image data through the model inversion were found to show distinctive patterns for melanoma, yielding sensitivity and specificity of cancer detection better than established dermatoscopy imaging methods [2].

Non-contact SIAscopy was developed solely within the School of Computer Science, funded by a Leverhulme grant (2002-2004, RF O'Dwyer) and a School fellowship (2002-2004; RF Preece). The main contribution was a theoretical framework for representing the imaging process as a two-stage mapping: between parameter vectors representing a tissue and its spectra; and the spectra and image values. This research defined generic mathematical criteria for determining the uniqueness of an inverse mapping (the necessary condition); and the mapping which minimises the tissue parameter recovery error (optimisation). The key insight that led to *non-contact SIAscopy* was that only the second stage was dependent on tissue geometry. By using image quotients instead of image values the factors related to tissue geometry were eliminated whilst preserving factors related to spectral reflectance of tissue, and hence its composition. Image interpretation was posed

as a solution to the inverse problem: of mapping between image quotients and tissue parameter vectors, demonstrating for the first time that it is possible to carry out quantitative analysis of tissue composition from *uncalibrated* images. Histological parametric maps could therefore be computed from images acquired from any distance and orientation.

3. References to the research

All the papers were published in high quality and high impact refereed journals (IF>4.3) and top conference proceedings. [1] won a prestigious IPMI poster prize. Editorial comment on [3] stated: "*Two papers (K.A.Vermeer et al. on polarimetric and E. Claridge et al. on dermatoscopic images) were selected in this special issue indicating the potential impact of new imaging modalities*." EPSRC IGR gave project [7] the top ranking ("Outstanding" / "Internationally leading") in *all* the assessment categories.

Publications

1. Cotton, SD, Claridge, E. Hall, P (1997) Noninvasive skin imaging. *Information Processing in Medical Imaging* (IPMI), (Duncan J, Gindi G Eds), LNCS 1230, 501-507. DOI: 10.1007/3-540-63046-5_50
2. Moncrieff M, Cotton S, Claridge E, Hall P (2002) Spectrophotometric intracutaneous analysis - a new technique for imaging pigmented skin lesions. *British Journal of Dermatology* 146(3), 448-457. DOI: 10.1046/j.1365-2133.2002.04569.x
3. Claridge E, Cotton S, Hall P, Moncrieff M (2003) From colour to tissue histology: Physics based interpretation of images of pigmented skin lesions. *Medical Image Analysis* 7(4), 489-502. DOI: 10.1016/S1361-8415(03)00033-1
4. Claridge E, Preece SJ (2003) An inverse method for the recovery of tissue parameters from colour images. *Information Processing in Medical Imaging* (IPMI), Taylor C and Noble JA (Eds.) LNCS 2732, 306-317. Springer. DOI: 10.1007/978-3-540-45087-0_26
5. Preece SJ, Claridge E (2004) Spectral filter optimisation for the recovery of parameters which describe human skin. IEEE Pattern Analysis and Machine Intelligence, 26(7), 913-922. DOI: 10.1.1.130.9362
6. Preece S, Styles I, Cotton S, Claridge E, Calcagni A (2005) Model- based parameter recovery from uncalibrated optical images. Medical Image Computing and Computer Assisted Intervention (MICCAI 2005) Palm Springs, California, October 2005. LNCS vol. 3750, 509-516. DOI: 10.1007/11566489

Grants

7. Image analysis based on an optical model of the skin for detection of early signs of melanoma. EPSRC (GR/M53035), August 1999 - March 2003, £210,000, PI: E. Claridge.
8. Image interpretation via material specific spectral characterisation models. Leverhulme Trust (ID20000477) (April 2002 – March 2004), £52,000, PI: E. Claridge.

4. Details of the impact

Introduction

According to Cancer Research UK over 12,000 people were newly diagnosed with malignant melanoma and more than 2,000 died from the disease in 2010. A critical factor in improving survival rates is early detection. General practitioners, who are the first point of referral, typically miss a third of malignancies whilst unnecessarily referring over 90% of benign lesions to dermatology specialists. *SIAscopy* is a technology that has improved GPs' diagnostic performance, potentially benefiting over 20,000 people that have been screened for melanoma by 2011.

Development

Contact SIAscopy was developed in Claridge's group [1] and subsequently patented (GB97/03177 1997-1998). Broad publicity from the BBC, the national press and professional magazines attracted commercial interests from Cambridge Design Partnership (CDP) [17-1] who acquired IP

rights and employed Dr Cotton (1998). A successful EPSRC-funded pilot study in partnership with CDP [2,3,7] led to the formation in 2000 of the spin-off company Astron Clinica, set up to manufacture and market *SIAscopy*-related products. The first clinical device (CE-marked) was released in 2000 and FDA-approved in 2002.

Non-contact SIAscopy was developed within a Leverhulme Trust grant [4,5,6,8] and patented (GB03/003367 2003-2004). Full IPR were acquired by Astron Clinica (2005) who developed a range of products: *Dermetrics*, *MoleManager*, *MoleMapping* (clinical); *BeauVisage* (consumer cosmetics) and *Cosmetrics* (industrial research, in partnership with P&G).

Commercial exploitation

Through a number of asset and IPR acquisitions *SIAscopy* products were first controlled by Astron Clinica, then Biocompatibles and are now marketed by MedX (key product: *MoleMate-SIMSYS*). *SIAscopy* devices are sold worldwide to public health outlets, private dermatology clinics, research organisations and cosmetics salons and clinics.

Commercial impact: skin cancer

Astron Clinica (until 2009) provided employment in R&D, design, manufacturing, trial management, marketing, management and administration for between 7 and 24 people per annum in Cambridge and Australia [17-2].

Biocompatibles (2009-2011) estimated that "*MoleMate* is in use in more than 200 primary care clinics world-wide including more than 100 in Australia and over 30 in New Zealand […], with more than 20,000 patients having been examined. *MoleMate* is 510k cleared in the U.S." [17-3].

According to MedX (2011-present) "The U.S. market alone is estimated to be a $1 Billion dollar opportunity, and *MoleMate* and *SIMSYS* are the only FDA approved and patent protected *SIAscopy* products in this important health segment." [17-4].

Since 2011 *MoleMate* has been used by ScreenCancer Inc. to provide cancer screening services to self-insured employers and insurance plans in Australia, Europe and the U.S. The initial agreement is valued at over $190,000CDN for 2011 alone [17-5]. In February 2012 Health Canada approved *MoleMate* for use by Canadian physicians [17-6]. Many private dermatology clinics both within and outside UK and EU (Australia, Canada, China, Malaysia, New Zealand, Russia, South Africa, UAE, USA) use *SIAscope* as a part of their services.

P&G, LenioMed Ltd and ScreenCancer are funding the expansion of the underlying technology into new consumer and wound care markets [17-7].

Clinical impact: skin cancer

GPs trained to use *SIAscopy* improved their recognition of suspicious lesions and reduced assessment time [9]. They demonstrated higher diagnostic accuracy for melanoma and made fewer unnecessary referrals to specialist clinics in comparison with GPs using conventional techniques [10-13].

Nurse-led triaging using *SIAscope* was shown to reduce the number of benign lesions seen unnecessarily by a consultant whilst detecting most melanomas, thus saving costs [14].

A large NHS Trial (2008-2010) [10] showed that diagnosis using *MoleMate* had strong agreement with expert assessment. In primary care setting it performed better than GPs' current practice and similarly to GPs' best practice [9]. Appropriateness of referrals was reported as lower (by 7.7%) [15] but cost-effectiveness was significantly higher (ICER= £1896) than best practice alone [16]. "Clinicians were confident that the *MoleMate* system enhanced their practice, and patients ranked satisfaction with consultations higher with the *MoleMate* system than with best practice alone" [15]. Clinicians using the technology gave consistently positive testimonials [18-1,18-2].

Cosmetics impact

Although developed primarily for the health-care market, *SIAscopy*-based product *Cosmetrics* has been used in the cosmetics industry research to increase the formulation efficacy of products such as UV protectants (P&G [18-3]). IRSI found *Cosmetrics* to "radically shrink the work and costs

involved in proving the effects of [skin] products"[18-4].

P&G jointly with *Astron Clinica* developed an in-store scanning system for consultation in the retail environment [18-5,18-6]. It was used by *Olay* as an in-store beauty care system (e.g. *Boots*) [18-7]: "The *Beau Visage* machine provides skin analysis using a medically proven skin imaging and consultation system. *Beau Visage* utilises SIA, the only technology which [...] images the blood supply (capillaries), melanin (pigmentation), and sun damage to your face." [18-8].

5. Sources to corroborate the impact

External independent references providing evidence for clinical impact of SIAscopy

9. Wood A, et al. (2008) Evaluation of the MoleMate training program for assessment of suspicious pigmented lesions in primary care. Informatics in Primary Care, 16(1), 41-50.
10. Walter FM et al. (2010) Protocol for the MoleMate UK Trial: a randomised controlled trial of the MoleMate system in the management of pigmented skin lesions in primary care. BMC Fam Pract. 2010 May 11;11:36.
11. Emery JD et al. (2010) Accuracy of SIAscopy for pigmented skin lesions encountered in primary care: development and validation of a new diagnostic algorithm. BMC Dermatology 10:9.[doi:10.1186/1471-5945-10-9]
12. Hunter JE: . (2008) Triaging suspicious pigmented skin lesions in primary care using the SIAscope. MD Thesis, University of Cambridge; 2008.
13. Hunter J, Moncrieff M, Hall P, Walter F, Emery J, Cotton S and Burrows N (2006). The Diagnostic characteristics of SIAscopy versus dermoscopy for pigmented skin lesions presenting in primary care (Poster). British Association of Dermatologists, UK, July. [http://simsys-molemate.com/articles-clinical-papers/the-diagnostic-characteristics-of-siascopy-versus-dermoscopy-for-pigmented-skin-lesions-presenting-in-primary-care/]
14. K. Govindan et al (2006) Assessment of nurse-led screening of pigmented lesions using SIAscope. Journal of Plastic, Reconstructive & Aesthetic Surgery 60(6), 639–645 [doi: 10.1016/j.bjps.2006.10.003]
15. Walter FM et al. (2012) Effect of adding a diagnostic aid to best practice to manage suspicious pigmented lesions in primary care: randomised controlled trial. BMJ 2012;345:e4110.[doi: 10.1136/bmj.e4110]
16. Wilson EC et al. (2013) The Cost-Effectiveness of a Novel SIAscopic Diagnostic Aid for the Management of Pigmented Skin Lesions in Primary Care: A Decision-Analytic Model. Value in Health, 16(2), 356-366. doi: 10.1016/j.jval.2012.12.008
17. http://www.cs.bham.ac.uk/~exc/Research/SIAinbusines.php. Examples of testimonials from business
18. http://www.cs.bham.ac.uk/~exc/Research/SIAtestimonials.php. Examples of testimonials from clinicians and beauty practitioners.