Institution: University of Southampton

Unit of Assessment: 13 Electrical and Electronic Engineering, Metallurgy and Materials.

Title of case study: 13-06 Walk This Way: Leading the World in Gait Biometrics

1. Summary of the impact

Gait recognition research has produced impacts on public policy, on national security processes, on forensic service practice, on culture and society. The notion that people can be recognised by the way they walk was invented as a totally new means to identify people and has gained increasing popularity, reflected by its inclusion in an episode of BBC premier series Spooks. This followed considerable scientific development after its invention at Southampton in 1994, culminating in impacts that include its integration in a commercial system piloted by the National Physics Laboratory, novel forensic use in a criminal conviction, its take up by researchers at the Serious Organised Crime Agency and its focus by The Forensic Science Society. Southampton has retained its position at the forefront of gait biometrics research, collaborating nationally and internationally and driving prolific media engagement that has furthered this new technology and increased its global impact

2. Underpinning research

Note: references (Section 3) are given as [3.n] and corroborations (Section 5) as [5.n]

Having established the University of Southampton as a world leader in biometrics, research at the School of Electronics and Computer Science (ECS) pioneered gait biometrics nearly 20 years ago. Given its applicability to the security field, the work led by Mark Nixon, Professor in Computer Vision (at Southampton since 1983) and John Carter, Senior Lecturer (at Southampton since 1985) was initially funded for US$1.3 million by the United States' Defense Advanced Research Projects Agency, under its Human ID at a Distance program [3.1] between 1999 and 2002. Further funding came from the Ministry of Defence [3.2] the US Army Research Laboratory [3.3] and the European Union, enabling the creation of extensive multimodal databases containing large gait image-datasets. So far, this research has involved 29 PhD students and 10 RAs at Southampton.

The underpinning research required new techniques in computer vision to enable the automated understanding of walking motion in video sequences [3.4]. Nixon and Carter developed the first model-based approach (the first research paper internationally to mention gait as a biometric [3.5]) and some of the first model-free approaches. Carter led the development of the world's first 3D biometric tunnel (funded by the MoD [3.2]) a constrained environment designed with public places such as airports and shopping centres in mind. Equipped with eight synchronised cameras, the team collected a variety of non-contact biometrics, capturing gait from different angles as a subject walked through the tunnel. One gait database featured images of more than 100 subjects and has around 300 registered users from over 30 countries.

Carter and Nixon developed the first intrinsically viewpoint-invariant approach [3.6] relying on a single camera without calibration, and worked with a wide range of camera views making it ideal for covert surveillance use. Nixon and Dr Sasan Mahmoodi (at Southampton since 2008) were the first to demonstrate time invariance in gait [3.7] disproving earlier understanding that gait changes over time. In collaboration with Dr Sarah Stevenage, Lecturer in Psychology (at Southampton since 1993) the team developed the first video-based analysis of people's ability to recognise others by gait [3.8]. They were the first to translate gait biometrics to forensics use [3.9] (thereby rendering gait biometrics compliant with Daubert rules and the recent Law Commission proposals, for use by expert witnesses) and to study spoofing of vision-based gait biometrics (demonstrating ability to withstand attempts to fool the system by mimicking another person's gait).

Nixon has delivered a host of keynote speeches at top international academic conferences, from IEEE Face and Gesture FG04 (South Korea, 2004) through IEEE Biometrics Theory and Applications BTAS (Washington, 2009) to IEEE Advanced Video and Signal-Based Surveillance AVSS (Krakow, 2013). Nixon co-authored the first textbook on gait biometrics *Human ID by Gait* and co-edited a special edition on gait in *IEEE Transactions SMC* (B) **40**(4) 2010, a top journal of

its type. As a direct result of Southampton's research, 'gait biometrics' first appeared as a conference session at one of the top international conferences in biometrics in 2003 and now features as a keyword in leading annual biometrics conferences. Nixon co-organised the first session on Biometrics and Forensics at the 2010 *European Signal Processing Conference* and co-chaired the first International *Workshop on Biometrics and Forensics* in Lisbon 2013.

Southampton's work is responsible for a new research arena. The extension of gait into the new field of soft biometrics, initiated in joint work with the US Army, bridges psychology and computer vision, recognising people by incorporating human evidence in the processing chain. These biometrics techniques are leading to new methods for attribute generation and recognition as in the new EPSRC Superidentity project, led by Stevenage, that encompasses aspects that we reveal both in the real world and in the cyber world [5.11]. Gait and soft biometrics were the subject of Nixon's plenary at the 10th IEEE International Conference on *Advanced Video and Signal-Based Surveillance* 2013 - the top international forum for disseminating new research in surveillance technologies [5.13], and of interest in forensic science [5.14].

3. References to the research (the best 3 outputs illustrating quality of research are starred)

*****[3.1] M. S. Nixon and J. N. Carter, Automatic Gait Recognition for ID at a Distance, DARPA/ US Army, 1999-2002, US $1,300,000

[3.2] M. S. Nixon and J. N. Carter, Fusion of Novel Biometrics for Real-World Secure Environments, General Dynamics/ MoD Defence Technology Centre, 2005-2008, £2,240,000

[3.3] Knowledge-Based Information Fusion via Semantic Web Technologies, Army Research Laboratories (US)/ MoD/ IBM 2006-2009, $1,000,000 (Grant shared with Prof. Shadbolt)

[3.4] M. S. Nixon and J. N. Carter, Human ID Based on Gait, *Proceedings of the IEEE*, **94**(11), pp. 2013-2024, 2006

*****[3.5] D. Cunado, M. S. Nixon and J. N. Carter, Using Gait as a Biometric, via Phase-Weighted Magnitude Spectra, *Proc. IAPR Int Conf. AVPA*, 1997 (journal version in *Computer Vision and Image Understanding*, **90**(1), pp.1-41, 2003)

[3.6] M. Goffredo, I. Bouchrika, J. N. Carter, and M. S. Nixon, Self-Calibrating View-Invariant Gait Biometrics, *IEEE Trans. Systems Man and Cybernetics* **B**, **40**(4) pp 997 -1008, 2010

[3.7] D. S. Matovski, M. S. Nixon, S. Mahmoodi, and J. N. Carter, The Effect of Time on Gait Recognition Performance*, IEEE Trans. Information Forensics and Security*, **7**(2), pp 542-552, 2012

[3.8] S. V. Stevenage, M. S. Nixon, and K. Vince, Visual Analysis of Gait as a Cue to Identity. *Applied Cognitive Psychology*, **13**(6), pp. 513-526, 1999

*****[3.9] I. Bouchrika, M. Goffredo, J. N. Carter, and M. S. Nixon, On Using Gait in Forensic Biometrics. *Journal of Forensic Sciences*, **56**(4). pp. 882-889, 2011

4. Details of the impact

Biometrics is about identifying people and is now emerging in regular use. Just as fingerprinting transformed policing, gait biometrics is fulfilling the potential to revolutionise the methods employed by security agencies to identify criminals and terrorists [5.1] and to make life convenient. Research at Southampton has advanced gait as a biometric from concept to reality and it is now recognised internationally as a technique ripe for societal and commercial exploitation [5.2]. Academics have actively engaged with military, national police bodies, security agencies, government departments and the international media in their research, to deploy and raise the profile of gait biometrics and it receives increasing focus in forensic practices [5.14].

Impact on Forensic Practice

- The research has impacted on forensics, leading in 2008 to the first use in the UK of gait biometrics as a form of evidence in a successful criminal prosecution [5.3]. Detectives from

the London Metropolitan Police needed help identifying a man wanted for violent robbery and approached Southampton after learning of their work from media exposure. The offender had snatched a bag, with violence. He left no DNA and had obscured his face by a helmet, but using CCTV footage, the Southampton academics could identify him by his gait, beyond reasonable doubt.

- The Southampton team have ensured compliance with the Daubert standards and the recent Law Commission proposals on admissibility of expert evidence, to enable the technique to be used in forensic evidence [5.4]. Biometrics, especially gait, features prominently in The Forensic Science Society & California Association of Criminalists Conference, *Forensic Horizons* 2013 [5.14]

Impact on Culture and Society

- International broadcast coverage on news channels in all G20 countries and beyond including [5.7] BBC news, Sky News and ABC News' Good Morning America GMA has resulted widespread acceptance of Nixon and Carter's gait recognition techniques for forensic use and for individual recognition amongst forensic and security professionals (GMA has 4.6m viewers - the second most popular news programme in the US [5.8]).
- The first public demonstration on BBC1's Bang Goes the Theory (3 million viewers [5.6]) of recognising individuals through their gait, television coverage of 'gait spoofing' on Discovery's Planet Earth [5.12] and coverage on all the UK major newspapers and radio stations, resulted in increased public awareness and appreciation of the application of science to this important area of public safety.
- This sustained media exposure has succeeded in raising awareness of gait biometrics, a contributing factor in the inclusion of gait biometrics in the popular BBC One series *Spooks* (Series 10, Episode 1 18/9/2011, 5.63m viewers [5.6]) in 2013.

Impact on Security Policy and Practice

- This increase in awareness of the potential of gait recognition has been achieved through media coverage and lectures to industry and decision-makers: Nixon was invited to speak, alongside Sir Keith Vaz, at the 5th Police Policy Forum *Too Much Surveillance* in Oxford (2008) to an audience of UK surveillance policymakers [5.9]. Nixon also lectured on *Advances in Noninvasive Biometrics: Gait and Ear* to the Intellect Association (2010), the trade association for the information technology, telecommunications and electronics industries.
- Follow-ups to these talks included visits to the university by the Serious Organised Crime Agency (SOCA) [5.10], the Association of Chief Police Officers (ACPO), the ACPO Criminal Records Office and the Home Office's Secured By Design initiative.
- Southampton's gait analysis system featured in a range of technologies that were showcased to the Operational Capabilities and Development division for future use (according to Ralph Wilkins, a SOCA research officer in the Division) representing a significant impact of gait biometrics on policy and practice.
- The Forensic Science Society & California Association of Criminalists conference *Forensic Horizons* 2013 [5.14] gait (biometrics) features gait prominently, especially for surveillance analysis.

Economic and Commercial Impact

- The rising profile of gait biometrics has raised awareness of the approach in industry. The National Physics Laboratory (NPL) has sponsored an EngD student at Southampton who, together with their researchers, developed a commercial demonstration of a gait recognition system to track a recognised individual within a CCTV-monitored area [5.5]. The system was developed in conjunction with the Centre for Advanced Software Technology (CAST), the BBC and BAE Systems. NPL has earmarked the system for use in high-security

environments such as airports and is pursuing further commercialisation. An NPL press release said: "NPL is particularly focused on the standardisation of gait recognition measurement … Developing standards of gait recognition is necessary to sustain and develop critical security infrastructure including coded access to buildings and monitoring security threats [5.5]."

- The research has also led to the new Superidentity project, led by Stevenage, that encompasses aspects that we reveal both in the real world and in the cyber world [5.11]

The pioneering research at Southampton on gait biometrics has therefore led to impacts in society and public policy, through impact on forensics, policy and operational use. A new system has been developed and successfully used for identifying criminals leading to a successful conviction and to a pilot commercial system. As such, gait biometrics has been taken from concept to reality, with high impacts and a future that would not have occurred without the research carried out at Southampton.

5. Sources to corroborate the impact

[5.1] Thirdfactor is the major international site for news and insight on biometric technologies, including gait: http://www.thirdfactor.com/tag/Gait

[5.2] Position of gait wrt development and commercialisation: Global Security Intelligence http://globalseci.com/?page_id=44

[5.3] Investigating Officer of Metropolitan Police, Crime Management Unit http://users.ecs.soton.ac.uk/msn/Walker.htm

[5.4] The Way we Walk, *Solicitors Journal* - Expert Witness Supplement, Spring 2013, pp15-16 http://www.solicitorsjournal.com/litigation/experts/expert-witness-developments-biometrics?ip_login_no_cache=46900b8c97331b301bd2c594ba766469

[5.5] NPL Gait Recognition System analysis http://www.forensicmag.com/news/security-system-montitors-walking-gait and system http://www.youtube.com/watch?v=bhCR0UbW13Y .

[5.6] Viewing figures for *Bang Goes the Theory* debut show (Southampton's gait biometrics demonstration was the opening item) http://www.guardian.co.uk/media/2009/jul/28/bang-goes-the-theory-debut-tv-ratings . Viewing Figures for *Spooks* series 10 http://www.bbc.co.uk/news/entertainment-arts-14969985

[5.7] Example of media interest in gait biometrics http://www.youtube.com/watch?v=Voygv1uTF7c

[5.8] Viewing figures for Good Morning America news gait appearance http://tvbythenumbers.zap2it.com/2011/06/16/%e2%80%9cgood-morning-america%e2%80%9d-posts-smallest-total-viewer-margin-with-nbc%e2%80%99s-%e2%80%9ctoday%e2%80%9d-in-4-years-season-to-date/95801/; and http://www.mediabistro.com/tvnewser/category/morning-show-ratings

[5.9] Report of the fifth Oxford Policing Policy Forum: *Too Much Surveillance*, 8th Sept 2008 http://www.police-foundation.org.uk/uploads/holding/oppf/oppf5.pdf

[5.10] Continuing interest and contact with Serious Organised Crime Agency: http://users.ecs.soton.ac.uk/msn/Ralph.htm

[5.11] S. Stevenage et al., EPSRC Awards, GrantRef=EP/J004995/

[5.12] Discovery : *Daily Planet* http://en.wikipedia.org/wiki/Daily_Planet_%28TV_series%29

[5.13] *10th IEEE International Conference on Advanced Video and Signal-Based Surveillance* (AVSS). http://www.avss2013.org/keynote-lectures

[5.14] *Forensic Horizons 2013*, http://www.forensic-science-society.org.uk/Events/2013/20131106%20-%20ForensicHorizons