

Institution: Keele University
Unit of Assessment: B11 Computer Science and Informatics
Title of case study: Classification within forensic datasets
<p>1. Summary of the impact</p> <p>This Keele University research into advanced signal processing and classification methods has led to novel algorithms capable of isolating subtle patterns in complex data. This has been applied in two highly significant application areas: first to the problem of image source identification and second to the problem of unobtrusive but highly secure authentication methods. In the first case this has enabled images captured by mobile phone cameras to be reliably and evidentially linked to source devices. This has huge applicability to those fighting terrorism, paedophile rings and civil unrest by extending detection capabilities to mobile phones in an era in which they are rapidly replacing dedicated cameras. It helps to prove, for example, that a photograph entered as evidence was captured by a specific mobile phone. As most phones can be tied to their user or owner this is extremely important to the successful detection and prosecution of offenders.</p> <p>In the second case it has enabled criminal record checks to be carried out securely online where previous paper-based systems were both too slow for purpose (taking weeks or months) and inherently insecure, leaving key posts unfilled in the health care industries and education sector; so benefitting the public by solving a problem that was having a negative impact on the running of these public services.</p>
<p>2. Underpinning research</p> <p>Since the early 1990s, the University's Computational Intelligence and Cognitive Science group (and predecessor groups at Keele) has undertaken a significant programme of research into advanced signal processing, mainly sub-band coding and decomposition, and neural network procedures for classification (for example [1-3]), with an increasing focus on the classification of complex and high-dimensional features within forensic datasets [4,5]. These features allow the identification of, for example, specific materials or devices (such as gun metal or individual digital cameras) and hence aid significantly in the identification and prosecution of criminals.</p> <p>The group developed the first formulation of a singular value decomposition (SVD: a modern spectral analysis/estimation technique based on <i>component</i> analysis) algorithm for source camera identification [9]. This reveals unique patterns of non-uniformity in the CCD sensors used by cameras in mobile phones, and allows a photograph to be associated with a specific device. This had previously been addressed using wavelet techniques. The output of the SVD is further processed using <i>grand-tour techniques</i> [5] to identify the signal ranges within which the CCD noise pattern can be extracted. Cluster analysis is then performed within these signal ranges to characterise camera models, so identifying which camera took which image; this final stage of research and development was carried out in collaboration (2009-11) with the commercial partner (<i>Forensic Pathways Ltd</i>) [8,9] and its impact is discussed in section 4.</p> <p>Deriving from our early work on differential image processing [6], which developed a new approach to generating digital signatures, and our broader work (described above) on classical pattern</p>

recognition [5,7], the team recognised that behavioural differences between individuals can be treated as a form of sensor pattern noise and hence be used for biometric identification and authentication. Through an Advantage West Midlands (AWM) Proof of Concept Award ("*Digital-media Authenticated Electronic Disclosure Application System*") the group identified several key underlying characteristics necessary for the successful implementation of graphical password systems in distributed computing environments and developed a digital media based authentication protocol/system; this final stage of the research was carried out in collaboration with the commercial partner (*Criminal Records Direct Ltd.*, CRD, formerly Assuramed Ltd.) and its impact is discussed in section 4. An EPSRC Industrial CASE PhD studentship was awarded (2009-2012, £87,059, "*A practical framework for the development of Evaluation of Multifactorised Authentication Schemes for Secure Distributed Systems*") but was not taken up due to the company's concerns about dissemination in such a sensitive domain. Instead CRD funded the work to transfer the scheme developed through the proof of concept award into a live system and has subsequently employed five Keele graduates.

Key researchers:

Dr K P Lam (lecturer 1995-ongoing)

Mr D Collins (lecturer 1987-ongoing)

Dr C Day (lecturer 2001-ongoing)

Dr P Fletcher (lecturer 1988-ongoing)

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

The following are peer-reviewed international conference papers and journal articles.

[1] Lam KP and Furness A (1996). *On parallelisation of neural classification algorithms*. Proc. Second International Symposium on Parallel Architectures, Algorithms, and Networks, pp.337-340. doi: 10.1109/ISPAN.1996.509004

[2] Lam KP (1999). *Component-based design for parallel moment generators*. Proc. Parallel and Distributed Methods for Image Processing III, SPIE vol. 3817, pp. 137-145. doi:10.1117/12.365898

[3] Day CR, Austin JC, Butcher JB, Haycock PW and Kearon AT (2009). *Element-specific determination of X-ray transmission signatures using neural networks*, Non-Destructive Testing & Evaluation International, 42(5): 446-451. doi:10.1016/j.ndteint.2009.02.005

[4] Lam KP, Austin JC and Day CR (2007). *A coarse-grained spectral signature generator*. Proc. Eighth International Conference on Quality Control by Artificial Vision, SPIE vol. 6356, 63560S. doi:10.1117/12.736723

[5] Lam KP and Emery R (2009). *Image Pixel Guided Tours: A Software Platform for Non-destructive X-ray Imaging*, Proc. Image Processing: Algorithms and Systems VII, SPIE vol. 7245, 72450N. doi:10.1117/12.806043 (Also in REF2)

[6] Lam KP (2007). *Towards a Practical Differential Image Processing Approach of Change Detection*, Innovative Algorithms and Techniques in Automation, Industrial Electronics and Telecommunications, pp. 229-234. doi:10.1007/978-1-4020-6266-7_42

[7] Lam KP and Fletcher P (2009), *Concurrent Grammar Inference Machines for 2-D Pattern Recognition*, Proc. Image Processing: Algorithms and Systems VII, 724515, SPIE vol. 7245, 724515. doi:10.1117/12.806035

[8] Soobhany AR, Leary R and Lam KP (2011), *On the Performance of Li's Unsupervised Image Classifier and the Optimal Cropping Position of Images for Forensic Investigations*, International Journal of Digital Crime and Forensics, 3(1): 1-13, doi:10.4018/jdcf.2011010101 (Also in REF2)

[9] Soobhany AR, Lam PK, Fletcher P and Collins D (2013), *Source identification of camera phones using SVD*, Proc. 2013 IEEE International Conference on Image Processing. Available online: www.ieeeicp.org/Proc/pdfs/0004497.pdf (Last accessed 24/10/2013)

Grants

DTI 02/1993-02/1996 (part of the £5.7M DTI Neural Computing Technology Transfer Programme)

Keele/Axon (Automatic Identification) Club Initiative

Investigator: A Furness

Partners: DuPont, Royal Mail

EPSRC 26/09/2005-25/09/2007 £331,158

EP/C008138/1 Element-Specific X-ray Imaging for Security Applications

Investigators: PW Haycock, KP Lam, CR Day and AT Kearon

Partners: The Forensic Science Service, X-Tek Systems Ltd

INDEX 02/2008-05/2008 £3,000

EU, UK& Industry award "High Security EDA system"

Investigators: KP Lam, D Collins

Partner: Criminal Records Direct Ltd. (formerly Assuramed Ltd.)

The INDEX (Innovation Delivers Expansion) scheme was funded by Advantage West Midlands (AWM), Economic and Social Research Council (ESRC), Engineering and Physical Sciences Research Council (EPSRC) and European Regional Development Fund (ERDF).

Advantage West Midlands (AWM) 05/2009-10/2009 £40,600

Proof of Concept Award "Digital-media Authenticated Electronic Disclosure Application System"

Investigators: KP Lam, D Collins

Partner: Criminal Records Direct Ltd. (formerly Assuramed Ltd.)

4. Details of the impact

The Keele partner company Forensic Pathways Limited (FPL) provides digital forensic services to a range of bodies including police forces internationally. Our research has developed algorithms which can be used to assist in the identification of the device source of evidential images. FPL had a product called Forensic Image Analyser (FIA) which could successfully identify whether a digital image came from a particular digital camera, or if a particular digital camera created a particular digital image, for dedicated cameras. However, increasingly mobile phone cameras are replacing such dedicated cameras in society as a whole. The construction quality, proximity of noise-generating elements, and high compression ratios used in mobile phones makes this a much more challenging problem, rendering the existing method far less effective, and producing a high number

of both false positives and true negatives. Our technique provides a more sensitive and consistently reliable method, enabling their product to be used for these now much more common devices. This is a very significant tool in the armoury of those fighting a diverse range of crimes but notably terrorism, paedophile rings and civil unrest. The research is now embodied in FPL's products.

Criminal Records Direct Ltd. (formerly Assuramed Ltd.) conduct criminal record checks (CRCs) for the Criminal Records Bureau (CRB) and so deal with highly sensitive data. They required a simple but effective method of authenticating on-line users of their systems. They approached us looking for a more secure approach than password distribution, that could be rolled-out securely without relying on the distribution of authentication devices (which could constitute a security risk). Through an initial INDEX award and a subsequent AWM Proof of Concept Award, we developed a multi-factor authentication system utilising a biometrically generated graphical password. Essentially we identified concealed variations in drawing which were idiosyncratic to particular users. This became core to CRD's security-sensitive online system and enabled them to meet the Criminal Record Bureau's stringent security requirements to run online, which in turn enabled CRD to quadruple their turnover in three years. There has been no breach of their security systems to date, which for a small company is a significant achievement. The ability for criminal record checks to be carried out securely online is a vast improvement on the previous paper-based system which was both too slow for purpose (taking weeks or months for a check to be undertaken) and inherently insecure, leaving key posts unfilled in the health care industries and education sector. The success of the applications led to the company's acquisition by GB Group PLC for £1.6 million in June 2013.

5. Sources to corroborate the impact

Source to corroborate the impact in paragraph 1 of section 4:

- The Director of Forensic Technology & Information Services at Forensic Pathways Limited (FPL) can corroborate the claim that FPL have incorporated our work on sensor pattern noise analysis into their forensic image analysis product (<http://www.forensic-pathways.com/products-and-services/forensic-image-analyser>) and that prior to this they were unable to determine the source of pictures taken using mobile phone type devices (but that they are now), and that this is a very significant tool in the armoury of those fighting terrorism, paedophile rings and civil unrest.

Source to corroborate the impact in paragraph 2 of section 4:

- The then-CEO of Criminal Records Direct (who left CRD in July 2013 after he sold the company to GB Group PLC) can corroborate the claim that the proof-of-concept system developed by the group, for multi-factor authentication, was core to their security-sensitive online system; and that it was this that enabled them to meet the Criminal Record Bureau's requirements to run online, which in turn enabled CRD (formerly Assuramed Limited) to quadruple their turnover in three years. The business was recently acquired by the GB Group PLC in June 2013: see news archive of the Wall Street Journal at: <http://online.wsj.com/article/BT-CO-20130702-700685.html> (last accessed 24.10.2013)