Institution: University of Kent

Unit of Assessment: 9: Physics (Forensic Science)

Title of case study: Worldwide Improvements in Policing due to Increased Sales of Facial Composite Software

Period when the underpinning research was undertaken: 2003 to 2015

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Stuart Gibson	Senior Lecturer	2007–present
Dr Christopher Solomon	Reader	1994–2020

Period when the claimed impact occurred: August 2013 to present

Is this case study continued from a case study submitted in 2014? Yes

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

EFIT6 (formerly EFIT-V) is a commercially successful facial identification software system, developed by Visionmetric, a University of Kent spin-out company, and underpinned by research conducted in the School of Physical Sciences (SPS) between 2003 and 2015. EFIT6 is now used by police forces in 25 countries spanning 6 continents, with 378 systems currently in use worldwide compared with 124 in 2013.

Kent's research has resulted in a step change in the effectiveness of facial identification methodology, leading to: (a) significant improvements in policing worldwide; (b) positive social impact due to the improved identification of perpetrators committing serious crimes; and (c) the growth of Visionmetric Ltd, due to new licence sales in 14 countries that accounted for 61% of the business's total revenue (£1.39m of £2.3m over the six-year period commencing 2014).

Content Note: Impact strand b, as well as some examples presented as part of the evidence, refer to cases of rape and sexual abuse.

2. Underpinning research (indicative maximum 500 words)

Research problem

Before the introduction of our software system, all commercial facial-composite systems utilised a feature-based approach to construct visual representations of unknown offenders, subsequently used to identify them. These relied upon a witness describing a suspect's individual facial features (eyes, nose, mouth, etc). Established research acknowledged substantial weaknesses in this approach (e.g. Tanaka and Farah J. Experimental Psychology 46A 225 [1993]). In particular, the inability of humans to recall and describe faces accurately compared to their superior ability to recognise faces is well established, since facial recognition by humans does not function through decomposition into distinct features but through a holistic impression of the face. Therefore facial-composite systems relying on the need for recall and description do not match human cognitive processes, and are inherently inefficient and error strewn.

Kent research enabling a more effective approach to facial-composite construction

Research conducted in the Forensic Research Group led by Solomon and Gibson, and including notable postgraduates – A. Pallares Bejarano (Kent PhD 2002–6), C. Scandrett (Kent PhD 2003-7), M. Maylin (Kent PhD 2002–6, PDRA 2006-9), and J. Mist (Kent PhD 2010-14) – has enabled a fundamentally new approach to facial composite construction. Our method is embodied in an iterative process during which the witness selects faces that

resemble the suspect from image arrays presented on a computer screen. The process has been likened, by police officers who use the system, to a succession of police 'line-ups' in which the witness selects an increasingly improving likeness to the suspect at each step. Early work, supported by EPSRC **[G1, G2]**, explored methods for computerised facial synthesis that combined calculated sets of Karhunen-Loeve functions for the shape and texture of the face, coupled with an interactive search algorithm. The search algorithm enabled witnesses to converge on the required identity by manipulating the underlying Karhunen-Loeve coefficients. Outputs resulting from **G1** and **G2** include the first peer-reviewed article to describe the new facial identification method **[R1]** and the perturbation of the Karhunen-Loeve coefficients to aid recognition via the caricature effect **[R2]**. Subsequent outputs **[R3, P1]** detail the technical innovation embodied in EFIT-V, the first commercial application (2007-15) based on the Kent facial identification method.

Work leading to further improvements in the facial composite construction and its use in criminal investigations

Further work on the effective use of facial composites **[R5]** showed that accuracy to a target face could be improved by morphing (combining) two composite images of the same suspect by different 'witnesses'. Through this process, salient, consistent features are reinforced, whereas inconsistencies in facial appearance are diminished in the morphed image. Work on automatic face model building **[G3]** has enabled the software to be easily adapted to generate facial images that are representative of many different human populations, located in different geographical regions. The design of the evolutionary search algorithm was further improved **[R4]**. Specifically, experiments which assessed the human capability to differentiate between similar faces showed that it is possible to reduce the number of Karhunen-Loeve functions without any loss of performance, thereby improving the efficiency of the search algorithm. These insights relating to witnesses' interaction with the facial construction process were incorporated into an upgraded version of our facial identification system, EFIT6, that has been used extensively by police from 2015 to the present day.

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

[R1] Gibson, S. J., Solomon, C. J., and Bejarano, A. P. (2003). Synthesis of Photographic Quality Facial Composites using Evolutionary Algorithms. In proceedings of *BMVC*, pp. 1-10. doi: http://dx.doi.org/10.5244/C.17.23

(This is the first publication describing the overall system concepts and prototype EFIT-V system. The UK's top-ranking annual computer vision conference and ranked 11th worldwide in the subject area.)

[R2] Gibson, S. J., Solomon, C. J., and Pallares-Bejarano, A. P. (2005). Nonlinear, near photo-realistic caricatures using a parametric facial appearance model, *Behavior Research Methods* 37(1), pp. 170-181. doi: http://dx.doi.org/10.3758/BF03206412

[R3] Solomon, C. J., Gibson, S. J., and Mist, J. (2013). Interactive evolutionary generation of facial composites for locating suspects in criminal investigations, *Applied Soft Computing* [Online]. doi: http://dx.doi.org/10.1016/j.asoc.2013.02.010

(Journal impact factor 5.472.)

[R4] Mist, J., **Gibson, S. J.**, and **Solomon, C. J.** (2015). Comparing Evolutionary Operators, Search Spaces, and Evolutionary Algorithms in the Construction of Facial Composites, *Informatica*, pp. 135-145 [Online]. KAR: https://kar.kent.ac.uk/49161/

[R5] Davis, J. P., Simmons, S., Sulley, L. **Solomon, C. J.**, and **Gibson, S. J.** (2015). An evaluation of post-production facial composite enhancement techniques, *Journal of Forensic Practice* 17(4), pp. 307-318. ISSN: 2050-8794. doi: https://doi.org/10.1108/JFP-08-2015-0042

Patents

[P1] 'Generation of facial composites', WO2006008485A1. 26/1/2006. Inventors: **Stuart Gibson,** Matthew Maylin, Alvaro Palleres-Bejarano, and **Christopher Solomon.** KAR: https://kar.kent.ac.uk/85412/

Grants and Awards

[G1] Synthesis of Facial Composites for Improved Suspect Identification (EPSRC GR/S06738/01), April 2003–March 2005, £107,414.

[G2] SWISS – Significant Witness Identification of Suspects System (EPSRC GR/S98504/01), October 2004–September 2006, £106,161.

[G3] Improving Cybersecurity Using Realistic Synthetic Face Generation (EPSRC EP/M013375/1), July 2015–July 2017, £155,087. Yan Wang was employed on this grant as a PDRA under the supervision of Gibson; he is now a Senior Software Engineer at Visionmetric.

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

EFIT-V (2007-15) and its successor EFIT6 (launched in 2015) are commercial facial identification systems (hereafter 'The Software'), developed by Visionmetric Ltd, a University of Kent spin-out company, and underpinned by the facial identification technique described above. The Software has revolutionized the way eyewitnesses/victims create computerised facial likenesses of offenders through its innovative entire face, recognition-based approach.

Extent of national and international reach

The Software is currently used in 25 countries spanning 6 continents. During the REF2021 cycle, the number of systems in use by police forces worldwide grew to 378, compared with 124 across 70 forces at the end of July 2013 **[f]**. This growth is due to additional systems being deployed in 14 countries overseas, including nationwide coverage in Bangladesh (Police Bureau of Investigation), Colombia (La Fiscalia), France (Gendarmerie Nationale), and South Africa **[f].** Before 2013, the Software had predominantly been licensed to the police constabularies of the UK. Since then, the Software has remained the undisputed industry standard for facial composite construction in the UK, with 32 out of all 43 constabularies in England and Wales **[f]**, as well as Police Scotland (nationwide), currently using the updated EFIT6 system. This equates to approximately 80% geographical coverage. A Facial Imaging Officer (West Yorkshire Police) stated that the Software 'has become the standard tool in our investigations' **[i].** International sales of the Software increased significantly by 2020, and it is now recognised as 'state-of-the-art' **[a]** in composite construction across the world, as demonstrated by testimonies from police forces in South Africa (who provided the most detailed feedback), Sweden, and Canada **[a, h, j]**.

Change in working practice and improvements in policing

The Software operates in a fundamentally different way to the feature-based facial composite systems it has replaced. Accordingly, this has led to a step change in the working practices of facial identification practitioners worldwide, with significant improvements in speed **[a]** and accuracy **[a, i]** resulting in more effective delivery of facial identification services and ultimately more efficient policing. As Jonas Hildeby (Operational Analyst, Swedish Police) puts it: the use of the Software since 2014 'allows officers to focus time and effort on questioning suspects who show a strong resemblance to the EFIT image' **[h]**. The South African Police Service used the Software in 9,398 criminal investigations in 2019 alone **[a]**, and stated that ever since they implemented EFIT6 in 2016, 'there was an increase in production and vast positive feedback on arrests of suspects from the Detectives' **[a]**. West Yorkshire Police provided usage statistics for 2020 (400-500 EFIT6 images) which is indicative of the number of composite images created each year since 2014 **[i]**. Extrapolating this figure across 32 constabularies in which the Software is licensed would indicate that a minimum of 12,800 suspect composite images are created per year in England and Wales. Improvements in witness satisfaction have also been reported **[a, j]**, with Canada's Waterloo Regional Police Service stating: 'The software is easy to use, easy to explain and really empowers the victim/witness to have a moment in the driver's seat of the investigation' **[j]**.

Training courses on the new facial identification methodology have been delivered by Solomon and Gibson to more than 300 Police Officers in the USA (6 courses), Canada (6

courses), Colombia, South Africa, France, Slovenia, Poland, Bangladesh, and Chile since 2014. Police Officers from Jamaica, Malta, and Sweden have also been trained in the UK. Trainees report a positive change in their understanding of facial composite construction and believe that the use of the Software will make their work more efficient (training survey sample **[c]**). Positive feedback has also been received from the South African Police, where a 'train the trainer' course was delivered by Solomon and Gibson to experienced Police Sketch Artists in 2016 **[a]**. Our research findings relating to the implementation of the Software are regularly incorporated into police training courses. For example, our research on composite morphing **[R5]** has been acknowledged as an 'incentive for innovating new working practices' **[i]** at West Yorkshire Police, where the technique has been in use since 2013**.** Morphing further enhances the accuracy of EFIT images by combining two or more facial composites of the same suspect, produced by different independent witnesses.

Social and cultural impact

Facial composite images produced using the Software are very much in the public eye, with appeals to identify suspects and news of resulting arrests appearing frequently in the media **[Fig. 1, d]**. Provided here are some examples that have led to the arrest of suspects in connection with serious sexual offences **[Fig. 1**, **e**, **i**, **j]**, distraction burglary **[h]**, horse mutilation **[d]**, and other serious offences **[b],** which were produced by witnesses working with West Yorkshire Police, Swedish Police, French Gendarmerie, and the South African Police Service respectively between 2015 and 2020. In the 'Beeston Bus Stop' rape case (6 March 2015), Detective Superintendent Nick Wallen of West Yorkshire Police testified on BBC Crimewatch **[d]** to the strong resemblance of the composite image to the suspect who was later arrested in Slovakia. **Fig 1** below describes another high-profile rape case where the Software was successfully used in the identification of the offender. Not only has the Software been used in real police investigations but it has also featured in fictional crime drama, and this serves to further highlight how it has become embedded in UK culture. The Software appeared, for instance, in Series 1, Episode 5 of the BBC crime drama *Bodyguard* (16 September 2018), where viewing figures averaged 8.3 million.

Fig 1: Metropolitan Police May 2017. Female victim raped in Victoria Park in East London. EFIT6 image (left) completed three days later, resulting in the immediate identification of repeat offender Derry McCann (right image), subsequently jailed for life at the Old Bailey.

Economic impact through the commercial success of Visionmetric Ltd

In the REF2021 period, Visionmetric, the University of Kent's spin-out company, won a substantial number of tenders for new overseas business and was the clear market leader for facial composite software systems in the UK. By 2020, the Software had been purchased by law enforcement agencies in 25 countries. International sales accounted for 61% of the company's turnover between 2014 and 2020 **[g]**, and the total revenue from overseas sales alone was £1.39m **[g],** leading to the commercial growth of the company. Additional licence sales during this period were made in 14 countries. Notable sales include: Bangladesh 205k euros (2016), Colombia 110k US dollars (2016), France 205k euros (2018), and South Africa 455k GBP (2016) **[g]**. The French Gendarmerie Nationale is the largest customer by volume (150 systems nationwide) followed by the South African Police Service (61 systems covering all provinces). In England and Wales, each constabulary typically holds two licences, equating to 64 systems **[f]**.

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

[a] Letter from the South African Police Service to corroborate improvements in policing due to the Software.

[b] Examples of EFIT6 images leading to arrests in South Africa and corresponding custody suite images after arrests.

[c] Feedback from officers trained in using the Software.

[d] Selected media articles for which EFIT6/V images have been disseminated in the media.

[e] Letter of support from Hamilton Police, Canada, and an example of the use of the Software leading to an arrest.

[f] NEW international business since 2014.

[g] Letter from independent accountant to support economic impact claims.

[h] Letter of support from Swedish police and composite example.

[j] Letter of support from West Yorkshire Police and examples of morphing composites.

[j] Letter of support from Waterloo Police, Canada.