Institution: **University of Kent**

Unit of Assessment: **9, Physics**

Title of case study: **EFIT-V Facial Recognition Software**

1. Summary of the impact

Research conducted within the School of Physical Sciences (SPS) at the University of Kent has led to the development and successful commercialisation of facial identification software named **EFIT-V**. First sold in 2007, this software is now **used by more than 70 police forces internationally** and has revolutionized the way eyewitnesses and victims of crime create computerised facial likenesses of offenders. These images are circulated to police intelligence units, and the general public, leading to the identification and arrests of offenders. **Police Identification rates have jumped from 5% to 55% as a result of this software.** With a current annual turnover exceeding £250K, which is projected to reach £600K by 2015, Kent spinout company **Visionmetric** has made significant impact with **EFIT-V**, and achieved a position of commercial dominance in the UK, and around the world.

An offender in police custody recognised and identified using Kent's **EFIT-V** technology
(Image courtesy of Merseyside Police 2012)

2. Underpinning research

Before the introduction of **EFIT-V** in 2007, all existing commercial computerised **facial-composite systems** employed a feature-based approach, in which a witness is required to describe, and then select the best matching individual facial features (eyes, nose, mouth etc) from databases of stored images. Established research has documented **substantial weaknesses** in this approach [Tanaka and Farah J. Experimental Psychology 46A 225 (1993)]. In particular, facial recognition by humans does not function through decomposition into distinct features, but through a gestalt or holistic impression. Moreover, the inability of humans to recall and describe faces accurately compared to their superior ability to recognise faces is well established. Thus approaches emphasising the need for recall and description do not match human cognitive processes, and are inherently disadvantaged. Studies conducted prior to the introduction of **EFIT-V** suggested that the operational **identification rate** of police forces using feature-based systems worldwide was only **5%**. [McQuiston-Surrett et.al Psychology, Crime and Law 12 505 (2006)].

Research within SPS underpinning **EFIT-V** commenced in 1997 and continues to this day. Initial published work demonstrated the utility of a set of matched **2D polynomials** to estimate **optically distorted wavefronts**, and to represent and automatically classify impact craters efficiently (see references to research section). A key insight was that quasi-stochastic processes (impact craters being one example) are numerous and the extension of these methods to the stochastic pattern class of human faces yielded an extremely efficient parametric representation. Calculation of a Karhunen-Loeve basis set enabled a recognisable, near photographic quality facial image to be stored in just 50 bytes. Based on this, **Dr. Solomon** (SPS since 1994, Lecturer now Reader) led the development of both a prototype system for encoding the owner's face on a credit card's magnetic strip (reported in New Scientist Aug 29th 1998 and on Tomorrow's World, 1998) and FaceMail (winner of the UK and European stages of the EU-sponsored DICON (digital information contents) 2000 competition) (see section 5 for link to further details). FaceMail worked by attaching an encoded picture of the sender to the email-header providing a visual impression of

the sender to aid prioritisation and handling of spam messages.

In 2001, Solomon led a research team to begin exploring methods of computerised facial synthesis that combined calculated sets of Karhunen-Loeve functions for the shape and texture of the face with an interactive search algorithm that enabled witnesses to converge on the required identity by manipulating the underlying Karhunen-Loeve coefficients. Dr Gibson (SPS since 1994, UG, PhD, Postdoc and Lecturer) developed suitable statistical models across all varieties of human facial appearance. Research students made significant contributions, including A.Pallares-Bejarano (Kent PhD 2002–2006) who developed the most efficient stochastic/evolutionary search algorithm, M.Maylin (Kent PhD 2002–2006, PDRA 2006-2009) resolved issues of software implementation, computational efficiency and speed, and C.Scandrett (Kent PhD 2003-2007) who made significant contributions to automated age progression, which was ultimately employed in the commercial software.

Four successive EPSRC grants (Solomon, PI, 1-4 in Section 3) were secured to develop the underlying science and extend these ideas commercially. All four were rated Outstanding for potential benefits to society. Commercial potential was recognised early and two UK patents were lodged in 2005. The basic elements of the developed experimental system were published in 2003 (reference 2). Two key advancements that were subsequently implemented in the commercial **EFIT-V** system were automated caricaturing [Gibson et al, Behaviour Reseach **37** 170 (2005)] and automated age progression [Scandrett et.al Pattern Recogniton Letters, **27** 1776 (2006)].

A comprehensive account of the underpinning science has recently been published. [Solomon et al Applied Soft Computing **13** 3298 (2012)]. Key insights underpinning the impact of EFIT-V were:

1. Statistical techniques researched by the Kent group for treating stochastic processes (e.g. impact craters and atmospherically distorted wavefronts) could be extended to human faces with unparalleled efficiency.

2. The resulting compact representation provided a mathematical model of facial appearance that was better matched to human face recognition and cognitive processes than the crude feature based model employed in earlier commercial systems.

3. The model allowed eyewitnesses new, flexible ways to alter facial appearance (e.g. fully automatic age progression) and alteration of subjective attributes (e.g. weight loss/gain, hostility, health).

4. A viable stochastic search algorithm could be defined enabling the underlying model to be manipulated easily by human observers without technical or specialist knowledge to achieve satisfactory likenesses.

3. References to the research
Research Grants
Four EPSRC research grants supported the research carried out. All 4 were rated Outstanding for potential benefits to society:

1. EPSRC GR/S06738/01 "Synthesis of facial composites for improved suspect identification" Principal Investigator, Dr C.J. Solomon. April 1 2003 – March 31 2005". Amount: £107,414

2. EPSRC GR/ S98504/01 "SWISS - Significant Witness Identification of Suspects System" Principal Investigator, Dr C.J. Solomon. Oct 1 2004 – Sep 30 2006". Amount: £106,161

3. EPSRC EP/D040973/01: "Statistically rigorous age progression for the identification of missing persons" Principal Investigator, Dr C.J. Solomon. Jun 1 2006 – Aug 31 2009. Amount: £177,638

4. EPSRC GR/S57839/01: "Modal Analysis For Exact Forensic Comparison of Handwritten Documents" Principal Investigator, Dr C.J. Solomon. Feb 1 2004 – Jan 31 2005. Amount: £58,714

Patents
1. "Generation of facial composites", PCT/GB2005/002780. 25/7/2005. Inventors: C.J. Solomon, S.J. Gibson and A. Pallares-Bejarano

2. "Plausible Ageing of the human face", PCT/GB2005/002669. 06/7/2005 Inventor: C.J. Solomon.

Publications
Publication in the open literature was consciously restricted for reasons of commercial confidentiality. All listed authors below are either Kent academics or Ph.D students. Publications [1], [2] and [3] marked with a * best indicate the quality of the underpinning research.

1* L. Kay, A. Podoleanu, M. Seeger and C.J. Solomon, "A new approach to the measurement and analysis of impact craters" Int. Journal Impact. Eng., Vol.19, No. 8, pp739-753 (1997). http://dx.doi.org/10.1016/S0734-743X(96)00054-1. The use of matched polynomial sets to describe and classify impact craters.

2* S. J. Gibson, C. J. Solomon and A. Pallares-Bejarano, "Synthesis of photographic quality facial composites using evolutionary algorithms", Proceedings of the British Machine Vision Conference 2003, Vol 1, p.221-230). http://dx.doi.org/10.5244/C.17.23. Cited 41 times according to Google scholar, this is the first publication describing the overall system concepts and prototype EFIT-V system.

3* S. J. Gibson, C. J. Solomon and A. Pallares-Bejarano, "Non-linear, near photo-realistic caricatures using a parametric facial appearance model" Behaviour Research: Methods, Instrumentation and Computing, 37(2), 170-181, (2005). http://dx.doi.org/10.3758/BF03206412. This paper describes our use of the facial appearance model based on PCA to automatically generate photo-quality caricatures.

4. D.Wallis, M.J. Burchell, A.C. Cook, C.J. Solomon and N. McBride "Azimuthal impact directions from oblique impact crater morphology", Mon. Not.. R. Astron. Soc, 359, 1137-1149, 2005, http://dx.doi.org/10.1111/j.1365-2966.2005.08978.x. The most mature expression of our use of matched polynomial sets to describe and classify craters according to kinematic impact.

4. Details of the impact

Older facial composite systems perform poorly as they rely on the memory of victims or eyewitnesses under the guidance of trained police officers. However, in the absence of forensic evidence, facial composites often provide the only means of establishing leads in police investigations. The introduction of **EFIT-V** has revolutionised the production of realistic facial images of criminals in the UK and worldwide. Two representative testimonials are given below:

"*We decided after these tests [initial trials of EFIT-V] to have a "leap of faith" and go with EFIT-V… since then our naming rate has increased dramatically to around 55%*"
West Yorkshire Police 2009.

"*I thought it would be appropriate to let you know as soon as possible about the new product [EFIT-V]. Put simply, I love it…This has led to 6 cases so far getting "near as damn-it" likenesses.*"
Metropolitan Police (New Scotland Yard) 2010.

Beneficiaries and Impact
The impact of EFIT-V is summarised in the following points:

(1) The use of EFIT-V is quicker and better matched to the natural cognitive processes of witnesses, so officers can produce more accurate likenesses rapidly. As a result, it has become the new industrial standard used **in 85% of the 51 police forces in the UK**.

(2) The technology has led to a **major increase in reported identification rates** from police forces using the system. The feature based approach described above has historical identification rates at 5% [Tanaka and Farah J. Experimental Psychology 225 (1993)], whereas rates as high as 55% are reported with the use of **EFIT-V** as commented on by West Yorkshire police. Overall, since its release in early 2008, licensees have seen increases of more than 100% in useful intelligence (as reported in the Investigative Practice Journal of Police Professionals, the largest circulation police weekly). An extended study of its performance in the field involving more than 1000 interviews resulted in an exceptional 40% naming rate [Driver and Rowbotham, E-FIT user conference 2009]. Construction is also up to 100% quicker than for traditional, feature-based systems.

(3) It has spawned a **successful spinout company, Visionmetric**, which has exported the technology to countries around the world including Sweden, Singapore, Jamaica, Canada, Ghana, Colombia, Botswana, Malta, Chile, Macedonia, Canada, Slovenia, South Africa, and the USA. The company's current turnover exceeds £250K p.a. and is projected to reach £600K p.a. by 2015. Visionmetric's directors, Solomon and Gibson, are Kent SPS academics and the prime contributors to the underpinning research.

(4) It has played a **key role in apprehension** of hundreds of criminals, many involving very serious crimes.

5. Sources to corroborate the impact

The following persons may be contacted to corroborate the reported improvements in efficiency and identification rates in their particular operational practices:

[1] Detective Sergeant, Crime Performance and Strategy Unit, Wiltshire Police [Contact 1] *can corroborate the reported improvements in efficiency and identification rates relevant to the Wiltshire Police*

[2] Facial Imaging Officer, formerly of West Yorkshire Police, now retired [Contact 2] *can corroborate the reported improvements in efficiency and identification rates*

[3] Detective Constable, New Scotland Yard, Metropolitan Police [Contact 3] *can corroborate the reported improvements in efficiency and identification rates for the Metropolitan Police*

[4] Facial Identification Officer, Q-Block, Essex Police Headquarters [Contact 4] *can corroborate the reported improvements in efficiency and identification rates within the Essex Police area of responsibility*

The company website [5] **Visionmetric (**http://www.visionmetric.com/) and a website specifically designed to store REF 2014 related information (http://www.kent.ac.uk/physical-sciences/Impact/cjs-impact/index.html) provides evidence:

- that the **EFIT-V** software is based on the underpinning research undertaken at Kent

- that both the underpinning research and its commercial realisation have significantly impacted on police practice and received considerable popular exposure

- of the international user base of **EFIT-V** supplied by distributers across 18 countries

These websites also provides direct access to publically available material in the form of popular science and general interest articles, web pages, customer testimonials and financial statements of the company.