Institution: University of Reading

Unit of Assessment: 11 – Computer Science and Informatics

Title of case study: Ground-breaking, demonstrable system for fast, frictionless and secure traveller identification at borders

Period when the underpinning research was undertaken: Between 1 January 2012 and 31 December 2020

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:
James Ferryman	Professor of Computational Vision	1998 to Present

Period when the claimed impact occurred: Between 1 August 2013 and 31 December 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

Border security is a most complex combination of security, political, economical, and technical problems, and when resolved, can reduce the barriers to faster and safer travel. Research at Reading has directly responded to the technical challenge of harmonized, secure and rapid crossing of borders by travellers through the development, deployment and evaluation of ground-breaking processes and technologies for traveller identification and monitoring in two EU-funded projects: FastPass, and its follow-on, PROTECT. The resulting transformative traveller identification system is secure, fast, efficient, user-centric and deployable at all border crossings. A combination of proof of concept research and engagement with the whole industry and related policy sphere has shifted positions on border security. The Reading system has contributed to the implementation of the 2025 UK Border Strategy. Research at Reading has also been positively validated by border authorities in four EU Member States: Austria, Greece, Poland and Romania. The University of Reading's main industry partner has benefitted through creation of a new business unit, new products and competitively won follow-on research. Reading's work has directly informed policy makers and legislators; and new international standards have subsequently been developed in biometrics and next-generation digital travel credentials.

2. Underpinning research

Automated Border Control (ABC), specifically ABC eGates at airports, has, since the mid-2000s, enabled identity verification to be performed using passports more rapidly and accurately than traditional manual checking. However, the application of current day eGates still does not meet expectations with respect to performance (speed and accuracy) as well as availability, impacting on public acceptance. Specifically, commercial systems are limited by (1) the time taken to read the ePassport chip (typically between 15 and 20s), (2) the use of a single International Civil Aviation Organisation (ICAO) mandated biometric modality (typically the face) – which limits accuracy, and (3) lack of advanced means of detecting spoofing attempts and anomalous (including evasive) behaviour. Finally, the eGate market is fragmented: no supplier provides a single harmonized architecture which can be deployed across land, sea and air border types. In 2013, Professor Ferryman and his team at Reading embarked on research on traveller identification and monitoring to help overcome these challenges through two major research efforts: EC FastPass (between 2013 and 2017) and EC PROTECT (between 2016 and 2019), selected by the EC for funding for their high innovation and impact potential.

EC FastPass: The EC FastPass project was funded by the EU (27 partners, EUR15.6m, EUR883,000 to Reading, [G1]) and coordinated by the Austrian Institute of Technology (AIT). In consultation with a wide range of stakeholders, the Reading researchers set out to develop a

next-generation modular eGate that is flexible in that it can be adapted and deployed at air and sea border crossing points (with travellers 'on foot') as well as at land border crossing points (with travellers in vehicles). The key innovation proposed was a segregated two-step system to increase throughput: (1) pre-enrolment (with the traveller's face as token) at a kiosk; (2) face verification within the eGate (no travel document presentation required, reducing the 'transaction' time). The University of Reading was a core project partner leading the largest technological workstream on traveller identification and monitoring.

Reading developed core biometric and video surveillance technology modules, with key research contributions in four major areas: (1) multibiometric optimised fusion, including a novel multimodal face and fingerprint fusion algorithm which is robust in the presence of spoofing attacks [R1]; (2) improved cross-spectral iris recognition performance when using selective feature-level fusion and without increasing the length of the iris code [R2]; (3) abnormality detection based on a novel soft computing algorithm for unsupervised abnormal behaviour-detection [R3] applied for the first time to monitoring of travellers in queues based on stereo cameras; (4) development of novel rule-based software for ABC detection and alarming which fuses information from a wide range of sources (including biometric, video analytics, travel document reading, background checks) to compute a risk score for each traveller.

Notwithstanding FastPass's achievements, Ferryman identified, as a direct result of the research on traveller identification, key limitations. The eGate transaction time, albeit reduced, remained significant due to the physical gate mechanics and the process not being non-stop. Furthermore, only one or two biometric modalities are employed, limiting identification accuracy and increasing susceptibility to spoofing. Hence, Ferryman conceived a radical vision to completely eliminate eGates and create a harmonized no-gate, free-flowing border control system employing digital travel credentials and multimodal contactless biometric identification.

EC PROTECT: The resulting Reading-led EC PROTECT project (between 2016 and 2019) - 10 partners, EUR5m, EUR1.1m to Reading, [G2] - responded to this challenge and researched, devised, demonstrated and evaluated a secure, minimally-intrusive and usable free-flowing biometric-based identity confirmation system deployable at land, sea and air borders. Ferryman engaged with more than 50 stakeholders (including border authorities, travellers, legal experts, policy makers, technology and security experts) to establish the real user needs and consequently enhance acceptability of the applied research on free-flowing, biometric-based identity verification at the border. The research resulted in a set of novel concepts and processes, technical specifications, system design and implementation of an innovative two-step process: (1) A multimodal biometric enrolment kiosk; and (2) Contactless multimodal verification on-the-move, integrating travellers' smartphones (as vectors of biographic and biometric data) and advanced passports (including secure ultra-high frequency (UHF) technology).

Reading's research focussed on the development of a novel biometric corridor solution for on-the-move traveller identification integrating multimodal biometric fusion, counter spoofing and video analytics (person re-identification and tracking to support biometric matching and detect anomalies, e.g. evasion of the control) [R4]. The overall PROTECT multibiometric verification system underwent significant technical and user validation in accordance with international standards, including how to overcome practical issues that may be encountered in real-world deployments [R4]. Additionally, Reading's research addressed iris biometrics, specifically a novel convolution neural network (CNN)-based semantic segmentation of irises captured by mobile sensors which significantly improves iris recognition performance [R5], and a new framework for quality-based iris segmentation, with particular focus on unconstrained settings representative of traveller on-the-move scenarios [R6]. PROTECT has resulted in a ground-breaking traveller identification system which improves the security and efficiency of the border identification process, is applicable to land, sea and air borders, and incorporates strong user-centric features.

3. References to the research

The research resulted from competitive, peer-reviewed funding applications; it was published in peer-reviewed journals and conferences; internal peer review against REF criteria judged the overall outputs' profile to meet/exceed 2* quality through contribution of new and useful applied concepts, knowledge, methods and performance assessment in biometrics and surveillance.

[R1] Wild, P., Radu, P., Chen, L. and **Ferryman, J.** (2016). 'Robust multimodal face and fingerprint fusion in the presence of spoofing attacks'. *Pattern Recognition*, **50**, 17-25. ISSN 0031-3203 DOI: https://doi.org/10.1016/j.patcog.2015.08.007

[R2] Wild, P., Radu, P. and **Ferryman, J.** (2015) 'On fusion for multispectral iris recognition'. *8th IAPR International Conference on Biometrics (ICB2015),* 19-22 May, 2015, Phuket, Thailand, 31-73. ISSN 2376-4201 DOI: https://doi.org/10.1109/ICB.2015.7139072

[R3] Patino, L. and **Ferryman, J.** (2014) 'Multiresolution semantic activity characterisation and abnormality discovery in videos'. *Applied Soft Computing*, **25**, 485-495. ISSN 15684946 DOI: https://doi.org/10.1016/j.asoc.2014.08.039

[R4] Galdi, C., Boyle, J., Chen, L., Chiesa, V., Debiasi, L., Dugelay, J.-L., **Ferryman, J.**, Grudzien, A., Kauba, C., Kirchgasser, S., Kowalski, M., Linortner, M., Maik, P., Michon, K., Patino, L., Prommegger, B., Sequeira, A., Szklarski, Ł. and Uhl, A. (2020). 'PROTECT: Pervasive and useR fOcused biomeTrics bordEr projeCT. A Case Study'. *IET Biometrics*. 9(6), 297-308. ISSN 2047-4938 DOI: https://doi.org/10.1049/iet-bmt.2020.0033

[R5] Hofbauer, H., Jalilian, E., Sequeira, A., **Ferryman, J.** and Uhl, A. (2019). 'Mobile NIR iris recognition: identifying problems and solutions' (2018). *Proceedings of the IEEE 9th International Conference on Biometrics: Theory, Applications, and Systems (BTAS2018)*, 22nd October 2018, Los Angeles, USA, 1-9. ISSN 2474-9680 DOI: https://doi.org/10.1109/BTAS.2018.8698590

[R6] Wild, P., Hofbauer, H., **Ferryman, J.** and Uhl, A. (2016). 'Quality-based iris segmentation-level fusion'. *EURASIP Journal on Information Security*, **25**. ISSN 1687-417X DOI: https://doi.org/10.1186/s13635-016-0048-x

Research Grants:

[G1] European Commission: FastPass (A harmonized, modular reference system for all European automated border crossing points), between 1 January 2013 and 31 March 2017, overall budget EUR15,592,395.28. Grant agreement no. 312583.

[G2] European Commission: PROTECT (Pervasive and UseR Focused BiomeTrics BordEr ProjeCT), between 1 September 2016 and 31 August 2019, overall budget EUR4,981,752.50. Grant agreement no. 700259.

4. Details of the impact

Impact on border guards and authorities: FastPass developed a next-generation harmonized ABC eGate solution, integrating novel technology modules for traveller identification and monitoring [S6]. The reference implementation, for the first time, facilitated adaptability and deployment to all types of border (land, sea and air) based on an open-system architecture. The solution represents the first European solution for cars at land borders with ABC, as well as the first solution for cruise ships [S1a]. The overall FastPass solution was thoroughly evaluated at three different border control points: the Port of Piraeus in Greece, the Airport of Vienna in Austria, and the land border crossing point of Moravita in Romania, over several months. More than 10,000 travellers and approximately 200 border guards used the system, which provided a novel analysis and insight into different scenarios and their results from technical, operative, social and legal perspectives [S1a]. In 2020, the FastPass eGate solution was positively evaluated for clearance of people in vehicles at Dunkirk ferry port [S1b]. Finally, the Reading researchers contributed to an in-depth evaluation of the FastPass solution, on biometrics and monitoring, which resulted in a best practices report – 'Recommendations for future ABC installations' for setting-up, operating and assessing ABC systems' [S2] published via FRONTEX – the European Border and Coast Guard Agency – to EU border guards.

PROTECT's system is world-leading. It is the first example anywhere of a multimodal biometrics on-the-move system for border control incorporating mobile and advanced passports, applicable to all border crossing types. As well as a series of technical reports, the PROTECT system was demonstrated in two real-world locations in 2019: at London St. Pancras Eurostar international train station in collaboration with Border Force and Eurostar, and at a border guard training facility at Kętrzyn, Poland, in collaboration with the Polish Border Guard [S6].

Prof. Ferryman directly engaged with the UK Home Office: Border Force and Her Majesty's Passport Office (HMPO), and the Cabinet Office, as key stakeholders. The Cross-Government Border Delivery Group on Future Borders in the Cabinet Office stated that "*Overall the PROTECT outcomes have contributed to implementation of the 2025 UK Border Strategy.*" The 2025 UK Border Strategy is Her Majesty's Government's exploration on how new digital systems can improve trader and traveller experience at the border and make the UK more secure [S3]. These new digital systems include a contactless travel model, digital travel credentials and reduction in transaction times. The Cabinet Office stated that PROTECT has shown how "*the transaction time at the border can be reduced to zero for a fully contactless control*", enabling "*significant improvement in the flow of low risk travellers through the border*", that PROTECT increases deployment of ABC in sea and land borders, over existing use at airports only, and that PROTECT "*supports health protection in a post-pandemic environment*" [S3]. HMPO stated that that PROTECT has provided them with "*an appreciation of the infrastructure [supporting digital travel credentials] which would be required*" [S4] with the Cabinet Office adding that PROTECT "*enables a reduction in the need for fixed and costly infrastructure as used in existing control systems*." [S3].

Outside of the UK, the Polish Border Guard stated that the PROTECT is a solution to "*further improve the border traffic control process at the external borders of the European Union*" [S5]. Specifically, it *"provides the Polish Border Guard with a high level of biometric checks which helps them to deal with increasing vehicle flows. This means border guard experts can focus on high risk passengers, whereas low-risk passengers can go through the border control process smoothly and quickly*" [S6], a view similarly endorsed by the Cabinet Office [S3]. Finally, Professor Ferryman has produced a white paper on the outcomes of PROTECT which has directly informed FRONTEX [S7]. Overall, the PROTECT outcomes have been validated by significant authorities with direct responsibility for implementing future border control systems.

Impact on commercial sector: PROTECT's main industrial partner, Veridos GmbH, is a world-leading provider of identity solutions. PROTECT has been a *key driver in formation of a new organisational unit* within Veridos focussing on document verification, ABC, self-service enrolment kiosks, non-stop access control solutions and non-stop traveller verification. PROTECT has *directly led to the development and deployment of new products* (VeriGO® eAccess portal and of VeriGO® eVisa mobile app**),** exploiting PROTECT RFID (radio-frequency identification) and NFC (near field communication) innovations, and RFIs with customers for deployment of PROTECT sUHF (secure ultra high frequency) access control solutions beyond border security, for critical infrastructure protection. PROTECT *directly led to Veridos' decision to invest in, and lead on, a new competitively won* €7m EU research and innovation project D4fly, which directly exploits the PROTECT innovations in free-flowing biometric identification and integrates them into the wider identity lifecycle of a traveller [S8].

Impact on policy, data protection and legislation makers: The EC stated in their policy impact assessment of the PROTECT project: "*PROTECT provides the proof of concept of a new way to control border crossing using multiple new technologies, in particular using multiple biometrics. The faster pre-enrolment using modern solutions like the biometric corridor could speed up the border crossing process. The multi-factor identification process will also improve the security and efficiency of the border control process*." [S9a]. Ferryman quickly established that such innovations were ahead of current EU law in border security – they simply could not be implemented today. This is because the use of technologies such as smartphones and next-generation multimodal passports (incorporating additional biometrics beyond face and fingerprint) in the border control process is not in accordance with the current legal framework

for border crossings in the EU (the Schengen Border Code). These findings, which were welcomed by the EC, specifically led to the EC inviting Ferryman to present to policymakers in Brussels in November 2018, to establish changes in legislation needed to adopt PROTECT's innovations. With respect to wider political debate, Ferryman contributed to two Civil Service World round table discussions (first and second) on how PROTECT's innovations will change immigration and security systems for borders of the future.

PROTECT has given careful consideration to the implications of biometrics in terms of legislation, citizens' and residents' rights and freedom of movement. The PROTECT team has specifically sought ways to empower the public, putting them in a situation whereby they can see and understand their own personal data and how it is being used – especially in relation to development and use of a PROTECT smartphone app. The Information Commissioner's Office (ICO) noted that PROTECT's work, particularly on development of methods to mitigate potential data protection issues, has positively "*informed their work*," "*extended their expertise*," and overall has "*contributed to an increase in ICO's corporate level of understanding*" [S9b].

Impact on standards: According to the British Standards Institute (BSI), PROTECT has "*emphatically impacted international standardisation efforts [in contactless and frictionless forms of biometric identification], and the biometrics industry more generally"* [S10]. Specifically, Ferryman has informed the scope and content of a new international ISO standard (ISO/IEC WD TS 22604) on 'biometric recognition of subjects in motion in access related systems' [S10], providing guidance to practitioners on the use of biometric-recognition-in-motion technologies. Further, PROTECT's innovations have contributed to both the International Civil Aviation Organisation (ICAO)'s Logical Data Structure (LDS) 2.0 – the next evolution of ePassport standards – and ICAO's Digital Travel Credentials (DTC) – which temporarily or permanently substitute a conventional passport with a digital representation of the traveller's identity, two separate ICAO topics. Specifically, PROTECT contributed to several ICAO technical reports on LDS 2.0 (which form part of the upcoming 8th edition of the ICAO Doc 9303 on Machine Readable Travel Documents) and DTC [S8].

Summary: The ambitious ground-breaking research and strong engagement with stakeholders has led to a world-leading transformative traveller identification system. PROTECT demonstrably resolved intractable technical and acceptability barriers to faster and safer border crossings. This has resulted in the worldwide border security industry and related policy sphere dramatically shifting their position on seamless and secure travel and aligning future priorities. PROTECT has informed and delivered on the 2025 UK Border Strategy and been positively validated by border authority practitioners in 4 EU Member States. There have been direct benefits for industry, for policymakers and legislators, and on development of new international standards in biometrics and digital travel credentials. PROTECT is currently being taken up in follow-on EU funded research which targets the countering of emerging threats in the whole traveller identity lifecycle.

5. Sources to corroborate the impact

[S1] (a) FastPass final project report, 2017; (b) Hauts-de-France deployment, October 2020
[S2] Recommendations for future ABC installations, 2017
[S3] Testimonials from UK Border Force (Home Office), January 2021 and Cabinet Office, February 2021
[S4] Testimonial from HMPO (Home Office), December 2020
[S5] Testimonial from Polish Border Guard, October 2020
[S6] FastPass final video and PROTECT final video
[S7] White paper on 'Secure and Seamless Travel: The PROTECT project', 2020
[S8] Testimonials from Veridos, June and December 2020
[S9] (a) Impact excerpt from PROTECT final review report (European Commission), 2019
(b) Testimonial from Information Commissioners Office, June 2020
[S10] Testimonial from British Standards Institute, December 2020