

Impact case study (REF3)

Institution: Queen's University Belfast		
Unit of Assessment: UoA12		
Title of case study: Face Recognition for the Real World		
Period when the underpinning research was undertaken: from 2016 to 2018		
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:
Neil Robertson	Professor	2016-present
Period when the claimed impact occurred: from 2016 to 2020		
Is this case study continued from a case study submitted in 2014? N		
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p><i>AnyVision</i> (revenue 2018/19 USD[text removed for publication]) is the performance market leader in visual intelligence for the real world, having during 2016-2020 innovated new computer vision recognition technology surpassing human performance.</p> <p><i>AnyVision's</i> system, applied to standard, existing camera/computer installations, is more accurate, faster and less expensive than competitor systems which require controlled lighting/range and largely work on easy problems such as passport recognition.</p> <p><i>AnyVision's</i> first commercial deployment in Europe's third largest airport, Schipol, with more than 200,000 people passing through it per day, and thousands more in the "watchlist" generated only 1 false alarm. The system is currently deployed at multiple sites worldwide.</p>		
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>In 2015, the most advanced face recognition system (<i>Google FaceNet*</i>) required over 200,000,000 images for training a deep convolutional neural network manipulating more than 8,000,000 parameters and did not work on CCTV footage. UoA research innovated in three key areas which overcome these major constraints and produced a face recognition system that is presently better than any other.</p> <p><i>First</i>, realizing that face recognition in the real-world is in reality done on video footage, Prof Robertson introduced temporal data into the design of machine learning algorithms. In any single image, a crop of a person's face yields partial information regarding identity, but over time, successive images in a video fill that information gap, increasing certainty. He pioneered the methods for building this type of reasoning into Deep Neural Networks, R[1], R[2], R[3].</p> <p><i>Second</i>, CCTV cameras have individual noise profiles and compression artefacts. Robertson created models that are invariant to these noise profiles by intentionally corrupting some data, (a) to mimic the real-world sensor output, (b) to learn, automatically, how data changes between images (the reference image for a person) and video (how they appear in the real world), R[4].</p> <p><i>Third</i>, it is evident that the face has an underlying generative structure encoded in genetics. This has many implications, from facial symmetry to the amount of variance across eyes, nose, etc. Robertson devised a new neural network training strategy that enabled him to be able to factor identity attributes (face shape, nose shape) separately from non-identity attributes (facial hair, make-up, glasses, etc.). This makes his system invariant to non-identity</p>		

attributes and gives a significant (factor of 2 compared with FaceNet, [R2]) reduction in required training data, **R[1]**, **R[5]**.

Also, since by factoring out non-identity attributes, he can also search neural networks for neurons that are highly correlated to these attributes. Therefore, he is able to pioneer a task-specific way of model pruning that eliminates all the redundant computation in a neural network. This is 10x more efficient, and uses 100x less data, while still out-performing competitor solutions, **R[5]**.

Further, the same machine learning methods developed for facial recognition were then applied to body patterns, proving that metric learning can be applied to significantly improve re-identification of people based on full body images in video, **R[6]**.

**FaceNet is a face recognition system developed in 2015 by researchers at Google that achieved then state-of-the-art results on a range of face recognition benchmark datasets. <https://arxiv.org/abs/1503.03832>.*

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

R[1] Face recognition using a unified 3D morphable model, G.Hu, F.Yan, C.Chan, W.Deng, W. Christmas, J.Kittler, N.M.**Robertson**, European Conference on Computer Vision (ECCV 2016) DOI: [10.1007/978-3-319-46484-8_5](https://doi.org/10.1007/978-3-319-46484-8_5)

R[2] Attribute-Enhanced Face Recognition with Neural Tensor Fusion Networks, G. Hu, Y. Hua, Y. Yuan, Z. Zhang, Z. Lu, S. Mukherjee, T. Hospedales, N.M. **Robertson**, Y. Yang, International Conference on Computer Vision (ICCV) 2017 DOI: [10.1109/ICCV.2017.404](https://doi.org/10.1109/ICCV.2017.404)

R[3] Deep Multi-Task Learning to Recognise Subtle Facial Expressions of Mental States, G. Hu, L. Liu, Y. Yuan, Z. Yu, Y. Hua, Z. Zhang, F. Shen, L. Shao, T. Hospedales, N.M. **Robertson**, Y. Yang, Proc. European Conference on Computer Vision, (ECCV 2018) DOI: [10.1007/978-3-030-01258-8_7](https://doi.org/10.1007/978-3-030-01258-8_7)

R[4] Ranked List Loss for Deep Metric Learning, X.Wang, Y.Hua, E. Kodirov, G. Hu, R. Garnier, N.M.**Robertson**, IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR 2019) DOI: [10.1109/CVPR.2019.00535](https://doi.org/10.1109/CVPR.2019.00535)

R[5] Deep Metric Learning by Online Soft Mining and Class-Aware Attention, Wang, X., Hua, Y., Kodirov, E., Hu, G., **Robertson**, N., The Thirty-Third AAAI Conference on Artificial Intelligence: Proceedings. Association for the Advancement of Artificial Intelligence (AAAI 2019). <https://arxiv.org/abs/1811.01459>

R[6] Cross-view Discriminative Feature Learning for Person Re-Identification, Borgia, A., Hua, Y., Kodirov, E., **Robertson**, N. IEEE Transactions on Image Processing (IEEE 2018). DOI: [10.1109/TIP.2018.2851098](https://doi.org/10.1109/TIP.2018.2851098)

Computer Science research predominantly follows a conference-first publishing strategy, where conference submissions generally receive 5 thorough reviews of experts in the field, and acceptance rates are often below 20%.

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

AnyVision has developed proprietary AI solutions based on UoA research **[R1]-R[6]** oriented around real world applications relating to faces, bodies and objects. With seamless integration and plug and play technology, AnyVision enables any camera to be smarter by indexing and analyzing everything the camera sees in real time.

AnyVision's, EVP Research said, "Academic research has been essential to the development of our technology, specifically the research in computer vision, artificial intelligence and scalable computing at Queen's University Belfast, under the leadership of Professor Neil Robertson", S[1].

The company's core product, *Better Tomorrow*, is an advanced tactical recognition system powered by a deep neural network. It alerts operators when people on a watchlist are captured on camera or tracks them as they move through an area, **S[1]**. The solution provides real-time face recognition that is operational after [text removed for publication] minutes of training on an existing camera network, offering immediate identification at a rate that is [text removed for publication] faster with much lower false positives than other commercial offerings. This is made possible, as uniquely, we deploy our own very low power mobile chips less than [text removed for publication]Watts, competitor systems require [text removed for publication]Watts General Purpose Processing units

AnyVision's other products, **S[1]** are built on the same core technology;

- *SesaMe*: a banking authentication application
- *Abraxas*: an access control system that has been developed in conjunction with Schneider Electric.
- *Insights*: a non-security application for the retail sector, providing analytics to help understand the shopper experience and shopping patterns in physical stores.

AnyVision's listed revenue in 2018 to 2019 was USD[text removed for publication] **S[2]**. To date, AnyVision has received USD[text removed for publication] in Series A investment including from [text removed for publication], and in 2020 pre-Series B investment worth USD[text removed for publication] from existing and new investors like [text removed for publication], **S[2], S[10]**.

By January 2020, AnyVision had signed up customers, **S[2]**, in more than [text removed for publication] countries, including state and local police departments, casinos, airports, stadiums, banks, large retail organizations, strategic partners and integrators including Verint, Bosch, **S[3]**, Nvidia **S[4]**, Genetec, **S[5]** and has engaged in extensive validation with Government agencies, principally the [text removed for publication].

AnyVision's system built upon UoA technology was shortlisted for the prestigious RAEng MacRobert **S[6]** award in 2019, the leading prize recognizing UK innovation in engineering.

Benefits to Society

Employment: **AnyVision employs over** [text removed for publication] **people in** [text removed for publication] **countries** (main offices in London, Belfast, New York, Tel Aviv).

National security: AnyVision leads the public security market. Any Vision technology is being used to prevent terrorism daily and catch known criminals "in the wild".

Quality of life: In response to the global coronavirus pandemic in 2020 AnyVision's solution was deployed in the biggest hospital in [text removed for publication] for contact tracing and safety of patients and medical staff, **S[2]**.

Privacy: AnyVision has also signed the pledge to build and deploy ethical and responsible AI systems, as recently validated in an audit conducted by Microsoft, **S[2]**. AnyVision's systems ensure compliance with GDPR and maintain privacy by anonymizing faces at source. The deep learning methods employed act as high robust cryptography, preventing identity hacking. AnyVision currently has the only facial recognition system authorized in [text removed for publication] privacy regulator verified AnyVision's "body" (non-face) recognition

algorithm as “non biometric”. The system was deployed in the 2019 Carnival of Nice to enhance guests’ safety, **S[7]**.

Commercial Success

AnyVision has secured significant investment to develop its technology, including USD[text removed for publication] in its Series A funding round, with investors including [text removed for publication] **S[3]**, **S[8]**.

The SVP at Bosch Building Technologies, commented, “Our customers around the world are increasingly asking for ways of integrating person and object recognition software into our cameras; collaboration with AnyVision will allow us to fulfill this customer wish even better and offer an enhanced package of solutions.”

In November 2018, **Qualcomm launched a USD100,000,000 AI Investment Fund, announced that its first investment was in AnyVision S[9], “a world leading face, body and object recognition startup”.**

Qualcomm explained, **“We believe AnyVision’s use of on-device AI is quite innovative as it uses technology to run video analytics on the device, therefore mitigating privacy concerns” S[9]**.

AnyVision has multiple Fortune 500 clients continuing to place purchase orders and revenue-generating agreements are in place with [text removed for publication]. AnyVision is the exclusive intelligent video processing for [text removed for publication]. Commercial clients include [text removed for publication].

As an example, ‘SesaMe’, AnyVision’s banking authentication application, has been licensed (since 2019) to banks including [text removed for publication]. While ‘Abraxas’, AnyVision’s access control system is in production with [text removed for publication], **S[10]**.



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

S[1] AnyVision EVP Research Letter

S[2] AnyVision CSO letter

S[3] Bernhard Schuster, Bosch Press Release 2018

S[4] Dell Technologies and NVIDIA Metropolis with AnyVision

S[5] Genetec Technology Partner Solutions

S[6] RAEng Mc Robert Award Finalist

S[7] AnyVision system deployed in the 2019 Carnival of Nice to enhance guests’ safety

S[8] AnyVision closes \$74M Series A

S[9] Qualcomm Ventures article - 'Anyvision on Cracking AI Before It Was Fashionable'
S[10] USD[text removed for publication]series B Investment in AnyVision