Institution: University of the West of Scotland		
Unit of Assessment: 11: Computer Science and Informatics		
Title of case study: Data Driven Intelligent and Autonomous Systems		
Period when the underpinning research was undertaken: 2013 - 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:**
Prof Keshav Dahal	Professor	2013 - 2020
Prof Zeeshan Pervez	Professor	2013 - 2020
Dr Pablo Casaseca	Senior Lecturer	2013 - 2020
Prof Jose Alcaraz-Calero	Professor	2013 - 2020
Prof Qi Wang	Professor	2008 - 2020
Prof Xinheng Wang	Professor	2013 - 2017
Period when the claimed impact occurred: 2014 - 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

Ground-breaking technological advancements in data analytics by the UWS research team have led to wide-ranging socio-economic impacts globally. From smart farming adoption in Nepal, Bhutan and Thailand, marketing and sales (Golden Casket Ltd.), social housing indoor air quality improvements (BRS Technology Ltd.) to the I3Q smart trolley deployment in 19 Chinese airports (Wuxi Chigoo Interactive Technology Co. Ltd China) and award-winning search and rescue drone developments (Police Scotland and Swedish Police), the team have demonstrated the global reach and significance of their pioneering research.

2. Underpinning research

Data analytics research undertaken by **Artificial Intelligence, Visual Communication and Networks (AVCN)** research centre at UWS, involves three cohesive areas of *data anonymization*, *personalised service assistant*, and *video analytics*. Valuable insight gained from data analytics helped to develop the state-of-the-art and create impact in various sectors, including social housing, customer engagement, smart farming, journey planner, and search and rescue.

Data anonymization realising data-driven services

Ensuring privacy of data is of utmost importance for data-driven services. Supported by gLink project **[3.E]** we have thus developed a partition-based approach to handle the uncertainty in IoT data streams **[3.1]**, instead of widely-used structured approaches. From extensive review of the state-of-the-art in privacy preserving methodologies, it was evident that existing anonymization approaches could not support processing of IoT data streams, without significantly relaxing the privacy restrictions. In our approach, partitions were initialised based on tuple description of the IoT data streams - each partition conforming to data usability, and privacy requirements. This approach helped to achieve the desired level of data quality in the published data whilst ensuring privacy of the IoT data streams; thus, has been utilised in smart farming (SunSpace project **[3.C]**) and servicing sector (SmartLink project **[3.D]**). To ensure anonymised data can deliver intelligence for data-driven services, expiration-band mechanism (X-BAND) **[3.2]** was proposed to handle missingness in the live IoT data streams. X-BAND novel weighted distance function reduced missingness of published data, thus ensuring reduced information-loss and guaranteed privacy perseveration.

Personalised Service Assistant

To address the challenges of indoor location-based data analytics, Simultaneous Localization and Mapping (SLAM) was developed to utilise the measurement of ambient magnetic fields present in all indoor environments **[3.3].** Service Recommendation Systems (SRS) are mainly driven by data analytics to understand the context and improve the quality of service. SRS for individual users were extensively studied, however group-based recommendation never got reasonable attention by the research community. SLAM, on the other hand, used a pioneering, exponentially weighted particle filter to estimate the pose distribution of the object and a Kriging interpolation method was

used to update the map of magnetic fields. SLAM was embedded in a ground-breaking **Smart Trolley project** – utilising RFID, IRID (Infrared ID), geomagnetic data for locating and navigation of passengers at airports. The insight gained from analysed trajectory data through SLAM was utilised to route passengers to the boarding gates whilst ensuring their shopping preferences **[3.4].**

Video Analytics

To address the challenge of a lack of high-quality video data in hard environments, AVCN made advancements through the AALART project **[3.A]**. A new resolution-enhanced automatic target detection and recognition for extremely small numbers of pixels was developed **[3.5],** specifically useful for long-range and low-quality video-based surveillance. Video-based analytics mainly rely on high resolution and continuous video stream for detection and recognition of anomalies or regions of interest. The novel machine learning driven surveillance system is capable of detecting and recognising at extremely low resolutions: vehicles at 9×9 pixels, and humans and animals at 11×11 pixels.

Building on AVCN's research achievements, **novel machine learning algorithms** were developed based on extending the Tiny-YOLO (You Only Look Once) and combining Path Aggregation Network and additional image processing technologies **[3.5]** and **[3.6].** The video analytics system was demonstrated through drone-based video surveillance for Police Scotland's Search & Rescue (SAR) operations in collaboration with Thales UK and CENSIS **[3.B].**

3. References to the research

3.1 Otgonbayar, A., **Pervez, Z., Dahal, K.** and Eager, S., (2018), 'K-VARP: K-anonymity for varied data streams via partitioning', *Information Sciences*, 467, pp.238-255. https://doi.org/10.1016/j.ins.2018.07.057

3.2 Otgonbayar, A., **Pervez, Z. and Dahal, K.,** (2019), 'X-BAND: Expiration Band for Anonymizing Varied Data Streams', *IEEE Internet of Things Journal*, 7(2), pp.1438-1450. https://doi.org/10.1109/JIOT.2019.2955435

3.3 Wang, X., Zhang, C., Liu, F., Dong, Y. and Xu, X., (2017), 'Exponentially weighted particle filter for simultaneous localization and mapping based on magnetic field measurements', *IEEE Transactions on Instrumentation and Measurement*, 66(7), pp.1658-1667. https://doi.org/10.1109/TIM.2017.2664538

3.4 Naserian, E., **Wang, X., Dahal, K.,** Wangy, Z. and Wang, Z. (2018) 'Personalized Location Prediction for Group Travellers from Spatial-Temporal Trajectories', *Future Generation Computing*, 83, pp.278-292, https://doi.org/10.1016/j.future.2018.01.024

3.5 Martinez-Alpiste, I., **Casaseca-de-la-Higuera, P., Alcaraz-Calero, J.M.,** Grecos, C. and **Wang, Q.,** (2020), 'Smartphone-based object recognition with embedded machine learning intelligence for unmanned aerial vehicles', *Journal of Field Robotics*, 37(3), pp.404-420. https://doi.org/10.1002/rob.21921

3.6 Martinez-Alpiste, I., **Casaseca-de-la-Higuera, P., Alcaraz-Calero, J.,** Grecos, C. and **Wang, Q.,** (2019), 'Benchmarking Machine-Learning-Based Object Detection on a UAV and Mobile Platform'. In *2019 IEEE Wireless Communications and Networking Conference (WCNC)* (pp. 1-6). IEEE. https://doi.org/10.1109/WCNC.2019.8885504

Grants

3.A Casaseca, P., Luo, C., *Thales-Challenge: Low-pixel Automatic Target Detection and Recognition (ATD/ATR),*Scottish Funding Council, October 2015 to October 2016, GBP50,000

3.B Casaseca, P., Alcaraz-Calero, J., Wang, Q., *Smart Unmanned Aerial System for Real-Time Object Detection*, CENSIS, November 2018 to October 2019, GBP50,000

3.C Dahal, K., Pervez, Z., *SUNSpACe – SUstainable developmeNt Smart Agriculture Capacity,* EU Erasmus+, January 2019 to January 2022, EUR163,862 (~GBP142,600).

3.D Dahal, K., Pervez, Z., *SmartLink (South-east-west Mobility for Advanced Research, Learning, Innovation, Network and Knowledge),* EU, Erasmus Mundus, July 2014 to December 2018, EUR3,049,600.

3.E Dahal, K., Pervez, Z., *gLINK (Sustainable Green Economies through Learning, Innovation, Networking and Knowledge Exchange*), EU, Erasmus Mundus, July 2014 to December 2018, EUR3,036,625

3.F Gilardi, M., **Dahal, K.,** Johnston, J., Gisbert, H., *Developing intelligent applications for confectionary business*, InnovateUK: KTP with Golden Casket, April 2019 to March 2021, GBP115,717

3.G Pervez, Z., Konanahalli. A., Ramzan. N., *To embed IoT and machine learning capabilities for developing air quality monitoring framework for large scale deployment,* Innovate UK: KTP with BRS Technology, August 2019 to July 2021, GBP123,502

4. Details of the impact

Process of research leading to the impact: Research projects coordinated and participated by AVCN, supported 36 staff and student mobilities across 10 Asian research institutes, including lead author of **[3.1]** and **[3.2]**. Research advancements made through these projects has enabled 11 students to secure higher degrees (PhD, MPhil, and Masters). Research from these projects has resulted in two ongoing KTP projects in the areas of data analytics for indoor air quality, and ML-driven business intelligence with BRS Technology Limited, and Golden Casket. In addition to this, four PDRAs trained from SmartLink and gLink projects, secured KTP Associate, and Senior Research Scientist posts with BRS Technology Limited, KeyFM, Bradford University, and Mechatherm International Limited.

Economic impact: AVCN has successfully up-skilled conventional farming practices in **Nepal, Bhutan, and Thailand,** resulting from smart farming adoption and practices beyond Europe through EU SunSpaCe project. The project has already trained over 30 conventional farmers from **Chiang Mai** and **Khon Kaen** provinces in **Northern Thailand** through the train the trainer program **[5.1a, 5.1b]**. This training has up-skilled farmers to use IoT devices and AI-based data analytics techniques for smart farming to improve the agro-health, use of farming-resources, sustainable organic farming, and access global markets. The consortium acknowledges that the AVCN played "the pivotal task of developing data analytic models and associated learning materials for the training programmes".

Wuxi Chigoo Interactive Technology Co. Ltd China, in collaboration with AVCN deployed the I3Q smart trolley in 19 Chinese airports including **Guangzhou Baiyun (China's third-busiest, and the world's 11th-busiest airport)** serving dozens of millions of passengers annually **[5.2]** – resulting in a significant increase in revenue from advertising. The underpinning research **[3.3]** and **[3.4]** helped identify the group users, making recommendations based on spatio-temporal and contextual data. This industry-focused research has been featured in local and international news with a viewership of 2,000,000 (*e.g.* The National, Evening Times, The Herald, The Herald online, and Paisley Daily Express).

Police Scotland are using our new aerial drone system to help in searches for missing and vulnerable people. The system is now scheduled for trials with Swedish Drone Rescue in liaison with **Police Sweden**. This CENSIS (GBP100,000) funded search and rescue operations (SAR) has enabled AVCN's drone-based AI video analytics platform to be ported to the Police Scotland platforms, which are being deployed across their SAR teams - Glasgow, Aberdeen, and Inverness with a significant proportion of rural areas being remote **[5.3, 5.4].** The system ultimately saves

live by speeding up the highly resource intensive, dangerous and time-consuming process of tracing and tracking missing people in inaccessible geographies. The project has received a range of high-profile media coverage, particularly after it was reported by BBC News **[5.5a]** and UK Authority **[5.5b].** The project won the Knowledge Exchange/Transfer Initiative of the Year at the **Times Higher Education (THE)** Awards in 2020 **[5.9a].** The project also won the CeeD-Scotland Industry Awards 2020 - Innovation Award **[5.9b].** Furthermore, enhancements made to AI-enabled video analytics is applied to detect ground personnel with complex backgrounds in the SmartCrane project for the lifting industry in Oil & Gas, construction and other related sectors **[5.6, 5.7]**. Another AI-enabled video analysis application for Low-Pixel Automatic Target Detection and Recognition was covered by BBC **[5.8]** and won a 'Special Commendation' in the Multiparty Collaboration category at the 2018 Scottish Knowledge Exchange Awards **[5.9.c].** AVCN's AI-enabled video analytics demonstrates numerous applications in smart city, smart building and utility infrastructure management, intruder detection, and animal tracking, amongst others.

AVCN's data stream analytics research in the two ongoing KTP's with **BRS Technology Ltd [3.G]** and **Golden Casket [3.F]** embeds ML/AI expertise within the companies, creating commercial and financial growth opportunities **[5.10a, 5.10b].** The research has applications in the areas of indoor air quality, predictive maintenance, BI-informed sales decision-making and sales operations. In addition, these partnerships are set to deliver GBP5,290,000 accrued profit impact to the UK economy.

In the social housing sector, the technology can be used to enhance living conditions. The BRS Technology KTP focuses on indoor air quality monitoring for preventive mould development interventions. The AI-based analytics and privacy preserving achievements **[3.1],** and **[3.2]** are embedded into BRS Technology to develop a predictive analytics framework for condensation and mould detection. This has a **significant impact** on housing associations, supporting the **UK's ambitious target of at least an 80% reduction in net carbon emissions by 2050** and creating a healthy space for families, thus having research impact beyond the technological spheres. The BRS Technology testimonial is clear: "*This [project] KTP has significantly helped BRS Technology to demonstrate a clear growth trajectory to its core team thus* ***improving staff retention by 80%***" **[5.10a].**

On the other hand, the KTP project with confectionary company **Golden Casket** is utilising AVCN's BI and data analytics research to transform the way the company operates by providing mobile computing and dynamic customer service with BI informed decision-making capacity to improve customer engagement, marketing and sales resulting in a profit of more than **GBP3,000,000** over five years post-KTP. The project has addressed multiple challenges that currently inhibit growth: **improving customer engagement** (current and new), improving decision-making based on robust data analytics and **culture change** transforming the business into a sector leader in the use of digital technology **[5.10b].**

5. Sources to corroborate the impact

5.1 Testimonials from EU projects
- **a.** SUnSpace
- **b.** Kantipur Engineering College

5.2 News clips for Smart Trolley project

5.3 Testimonial from CENSIS for missing people project

5.4 Testimonial from Police Scotland

5.5 News clips on Police Scotland Project:
- **a.** BBC: Police to use AI recognition drones to help find the missing https://www.bbc.com/news/uk-scotland-50262650

b. UK Authority: Police Scotland combines drones with AI https://www.ukauthority.com/articles/police-scotland-combines-drones-with-ai/

5.6 Testimonial from Thales for AALERT project.

5.7 Testimonial from CENSIS for AALERT project.

5.8 BBC: Robots with better eyesight and intelligent drones https://www.bbc.co.uk/news/uk-scotland-scotland-business-40623890

5.9 Awards

a. Winner of THE Awards 2020 for the Category - Knowledge Exchange/Transfer Initiative of the Year (THE Awards UK 2020 (the-awards.co.uk)

b. Winner of the Scottish Centre for Engineering Education & Development (Ceed) 2020 award, https://censis.org.uk/2020/02/21/censis-partnership-wins-at-ceed-awards/

c. Special commendation Scottish Knowledge Exchange award 2018, Top Award for UWS Project at the Scottish Knowledge Exchange Awards | UWS

5.10 Testimonial from Knowledge Transfer Partnerships

a. BRS Technology Limited

b. Golden Casket Limited.