Guest Editorial
DENSE - Data Integrity, Integration and Security Issues for Consumer Data in Industry 5.0

FUTURE personalization services are key to Industry 5.0. Also known as the fifth industrial revolution, it leverages artificial intelligence and cognitive services for cooperation between machines and humans. This collaboration aims to increase consumer value while improving industrial automation. Industry 5.0 focuses more on cooperation than competition. Personalized services are provided by linking data from various sensors to highlight distinct product characteristics based on consumer preferences. A high-tech strategy uses the Internet of Things to provide industrial automation along with personalized consumer services through symmetric innovation via democratized Big Data knowledge.

Achieving personalization makes data central to Industry 5.0 efficiency gains. Emerging technologies like microelectromechanical sensors, smart devices, and the Internet of Things enable acquiring large consumer data volumes. However, issues remain regarding data integrity, heterogeneity, real-time analysis, and security. Consumer data must also factor into deriving industrial operations and end products. These issues can be summarized as data integrity, integration, and security to achieve agility, quality production, resilience and automation.

The goal of consumer data integrity, integration, and security in Industry 5.0 is to create a nexus between operations, preferences and information technology to improve manufacturing. Most attempts aim to improve human-machine collaboration, collaborative robots and automation software. However, less attention has been given to exploring techniques for data integrity, integration and security including privacy protection, heterogeneity, complexity computational, data quality and platform development. These are highly believed to not only improve industry productivity but also make manufacturing and production more sustainable and convenient for consumers.

The study by Hussein et al. [A1] highlighted the importance of data fusion and integration from multiple sensor modalities in the context of Industry 5.0. However, efficient data integration requires error-free and synchronized data acquisition. The authors in this work leverage the theory of sufficient statistics function to learn an approximation for channel state information in order to predict the upper bound error. The sufficient statistics is based on instance-aware optimziation using shallow learning techniques. This error is reduced using Bayesian optimization to determine the best model for channel distribution and compression. Experimental results reveal that the proposed work is efficient for data integration as it yields lower reconstruction loss while maintaining a reasonable model size.

An autonomous framework for initiating a covert intrusion attack and the design of intelligent intrusion detection system that can reduce the probability of malware attacks on cruise control system is introduced in the study proposed by Haghighi et al. [A2] to improve the security of autonomous vehicles in Industry 5.0 environment. To achieve a reasonable level of security, a novel design of controller area network along with covert intrusion method is proposed to launch an intentional attack on the cruise control system of autonomous vehicle, and a decision support system for detecting the intrusions are proposed. Stochastic analysis of the attack as well as the intrusion detection is carried out on publicly available datasets to measure the resilience of autonomous vehicles against worms and malwares. The results illustrate that the proposed method can effectively detect covert attacks in comparison to the existing methods.

Sharma et al. [A3] also emphasized on the security aspect of Industry 5.0, however, the study focuses on the design of an intrusion detection system for consumer electronic devices using shallow machine learning techniques and normalized weighted decision matrix. Authors have also proposed a feature selection method that could help in reducing the system overhead while improving the detection performance. Furthermore, the machine learning methods are optimized in order to deal with multiclass classification problem concerning the detection of multiple attacks within the same learning cycle. Experimental results reveal that the support vector machines (SVM) yielded the best results in comparison to other baseline approaches and existing works.

On the other end of spectrum, the affective domain aspect using audio-video modalities acquired using Unmanned autonomous vehicles (UAVs) in Industry 5.0 environment has been explored by Paikrao et al. [A4]. The authors focused on the integration of multiple data modalities for gesture recognition in order to provide personalized services to the consumers. A modulation domain recognition (MDR)-based gesture aware system is designed that not only improves the personalization of services but also helps the system to cope with noises commonly caused by machineries used in industrial environments. The tests have been conducted on benchmark datasets to show the efficacy of proposed approach.

Recently, deep learning methods, especially the generative artificial intelligence (GAI) methods have been used extensively to improve the downstream tasks such as detection and recognition. In this regard, Xu et al. [A5], focused on

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the data integration for generating and recognizing fault samples in Industry 5.0 environment using Three-layer subnet Wasserstein Generative Adversarial Network-Gradient Penalty (TLS-WGAN-GP). The fault data is generally considered to be scarce, which hinders the accurate fault detection performance. The three-layer subnet WGAN is trained to generate qualitative fault data for the upsampling, which is then trained with the discriminative methods to improve the recognition performance. Experimental results reveal that the TLS-WGAN-GP can help improve the recognition performance by 3%, respectively.

Vehicular networks are summoned by the newly emerged (semi-)/autonomous vehicles (AVs) which introduce new features and challenges in industrial networks. Processing of image and video modalities in autonomous vehicles is considered to be a challenging task in conjunction with the detection and recognition processes. In this regard, Singh et al. [A6] proposed a data integration approach that combines the image frames in multi-view settings to detect vehicles and perform traffic analysis in Industry 5.0 setting. One of the sustainability factor includes reducing the processing time, which in turn, saves energy. The authors in this study use lightweight deep learning approaches with dynamic skipping approach to increase the framework, thus by extension, improving the processing speed and reducing the inference time. Their experimental results revealed that the pretrained deep learning networks in combination with dynamic skipping approach can increase the frame rate upto 18 frames per second (FPS), while achieving a reasonable level of detection performance, i.e., 91.0%.

Industry 5.0 caters to large array of services including smart healthcare systems. However, smart healthcare systems not only require data integrity, integration, and security issues but also need the quality of service to be maintained in order to be usable by consumers. Zhang et al. [A7] explored the smart healthcare system paradigm within the context of Industry 5.0 using microservice deployment. The idea of the proposed work is to reduce the cost while ensuring an adequate level of quality of service (QoS). Such issues are considered to be constrained multi-objective optimization problem (CMOP) as they need combined optimization of task completion rate and cost. To address the aforementioned issue, authors proposed multi-objective optimization evolutionary algorithm (MOEA-PM) that adds a penalty constraint to the fitness function to the optimization process. Experimental results reveal that the MOEA-PM not only adapts well to microservices deployment strategy but also reduces the optimization cost, which is considered to be a foundation for realizing Industry 5.0.

Recent works have established that artificial intelligence, next generation networks, and emerging technologies are the key enabling technologies for Industry 5.0. One of the emerging technologies that is gaining a lot of interest from the research community is Blockchain technology. Anbalagan et al. [A8] explored the use of Blockchain technology to preserve the data integrity in autonomous vehicles. More specifically, the authors leverage shallow machine learning strategies optimized using stochastic gradient descent to perform intrusion detection in autonomous vehicles. The detection system further adds an extra layer of trust evaluation using blockchain technology, hence the term blockchain-based intrusion detection system (BIDS). Experimental results reveal that BIDS can outperform existing works in terms of intrusion detection performance by achieving 98.0% accuracy.

The manuscript by Xu et al. [A9] dive into the paradigm of data encryption while using Internet of Things (IoT) devices for data integration in Industry 5.0. Existing methods mainly focus on one-to-many predicate encryption technologies. However, the authors in this work proposed a privacy-preserving dynamic multi-keyword ranked search scheme that caters to many-to-many encryption scenario. Their privacy preservation scheme is derived using tree-based index structure along with Greedy Breadth-First Search algorithm to achieve the aforementioned task. Furthermore, a secure maximum generation protocol is utilized to support the dynamic updates in the data cloud storage. Security analysis results reveal that the proposed approach outperforms existing works in terms of cost efficiency as well as performance in multi-writer and multi-reader setting, respectively.

APPENDIX: RELATED ARTICLES

[A1] M. Hussien, K. K. Nguyen, A. Ranjha, M. Krichen, A. Alshammari, and M. Cheriet, "Enabling efficient data integration of industry 5.0 nodes through highly accurate neural CSI feedback," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 813–824, Feb. 2024, doi: 10.1109/TCE.2023.3294832.

[A2] M. S. Haghighi, F. Farivar, A. Jolfaei, A. B. Asl, and W. Zhou, "Cyber attacks via consumer electronics: Studying the threat of covert malware in smart and autonomous vehicles," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 825–832, Feb. 2024, doi: 10.1109/TCE.2023.3297965.

[A3] A. Sharma, S. Rani, A. K. Bashir, M. Krichen, and A. Alshammari, "A low-rank learning based multi-label security solution for industry 5.0 consumers using machine learning classifiers," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 833–841, Feb. 2024, doi: 10.1109/TCE.2023.3282964.

[A4] P. Paikrao, S. Routray, A. Mukherjee, A. R. Khan, and R. Vohnout, "Consumer personalized gesture recognition in UAV based industry 5.0 applications," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 842–849, Feb. 2024, doi: 10.1109/TCE.2023.3308209.

[A5] S. Xu, X. Xu, H. Gao, and F. Xiao, "TLS-WGAN-GP: A generative adversarial network model for data-driven fault root cause location," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 850–861, Feb. 2024, doi: 10.1109/TCE.2023.3300442.

[A6] K. N. Singh, N. Baranwal, O. P. Singh, and A. K. Singh, "SIELNet: 3D chaotic-map-based secure image encryption using customized residual dense spatial network," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 862–868, Feb. 2024, doi: 10.1109/TCE.2023.3227401.

[A7] H. Zhang, J. Luo, Y. Tu, R. Wang, D. Wu, and J. Yang, "Microservice deployment mechanism with diversified QoS requirements for smart health system in industry 5.0," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 869–880, Feb. 2024, doi: 10.1109/TCE.2023.3296534.

[A8] S. Anbalagan, G. Raja, S. Gurumoorthy, D. S. Rajendran, and K. Ayyakannu, "Blockchain assisted hybrid intrusion detection system in autonomous vehicles for industry 5.0," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 881–889, Feb. 2024, doi: 10.1109/TCE.2023.3320282.

[A9] D. Xu, C. Peng, W. Wang, H. Liu, S. A. Shaikh, and Y. Tian, "Privacy-preserving dynamic multi-keyword ranked search scheme in multi-user settings," *IEEE Trans. Consum. Electron.*, vol. 69, no. 4, pp. 890–901, Feb. 2024, doi: 10.1109/TCE.2023.3269045.

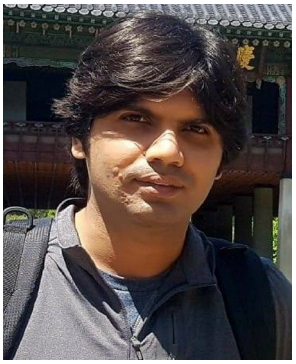
KAPAL DEV
Department of Computer Science
Munster Technological University
Cork, T12 P928 Ireland
E-mail: kapal.dev@ieee.org

CHIH-LIN I
China Mobile Research Institute
Beijing 100032, China
E-mail: icl@chinamobile.com

SUNDER ALI KHOWAJA
Faculty of Engineering and Technology
University of Sindh
Jamshoro 76080, Pakistan
E-mail: sandar.ali@usindh.edu.pk

Kapal Dev (Senior Member, IEEE) is currently serving as an Assistant Lecturer with the Department of Computer Science, Munster Technological University, Ireland, where, he was a Senior Researcher. Previously, he was a Postdoctoral Research Fellow with the CONNECT Centre, School of Computer Science and Statistics, Trinity College Dublin (TCD). He is very active in leading successful projects as a Principal Investigator under Horizon Europe MSCA Staff exchange, Erasmus + International Credit Mobility, Capacity Building for Higher Education, and H2020 CO-FUND Projects, and won over 1.2 million Euros funding in total. He is serving as a Funded Investigator at one of top European research centres–CONNECT, TCD funded by Science Foundation. Recently, he is working towards the standardization. He has published over 70 plus research papers majorly in top IEEE Transactions, Magazines, and Conferences. His research interests include wireless communication networks, blockchain, and artificial intelligence targeting applications majorly toward industry 4.0/5.0 and supervised more than 22 students at masters and Ph.D. level in the same areas. He is recently award as the IEEE ComSoc EMEA Outstanding Young Researcher in 2022 for promising research activities for the benefit of the Society. He is serving as an Associate Editor of *IEEE Consumer Electronics Magazine*, *Nature*, *Scientific Reports*, *Wireless Networks* (Springer), *IET Quantum Communication*, *IET Networks*, and *Human-centric Computing and Information Sciences* (Springer), an Area Editor in *Physical Communication* (Elsevier), a Technical Committee Member in Elsevier COMCOM, a Board Member of IEEE Future Directions Newsletter: Technology, Policy and Ethics, and a Review Editor in *Frontiers in Communications and Networks*. He performed duties as a Guest Editor in several Q1 journals, IEEE NETWORK, IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, IEEE TRANSACTIONS ON NETWORK SCIENCE AND ENGINEERING, IEEE TRANSACTIONS ON GREEN COMMUNICATIONS AND NETWORKING, *IEEE Standard Communication Magazine*, *Computer Communication* (Elsevier), *Computer Networks* (Elsevier), and *Computers and Electrical Engineering*. He served(ing) as the Lead Workshop Chair in one of ACM Mobicom 2022, IEEE Globecom 2022, IEEE Blockchain 2022, IEEE ICDCS 2022, IEEE CCNC 2021, IEEE Globecom 2021, IEEE PIMRC 2021, and ACM MobiCom 2021 Workshops. He is a TPC Member of IEEE Smart Cities 2022, IEEE BlackSeaCom 2022, IEEE Globecom2022, IEEE ICC 2021, IEEE ICBC 2021, and IEEE VTC2021.

Chih-Lin I (Fellow, IEEE) received the Ph.D. degree in electrical engineering from Stanford University. She is a Chief Scientist of Wireless Technologies with ChinaMobile. She has won the 2005 IEEE ComSoc Stephen Rice Prize, the 2018 IEEE ComSoc Fred W. Ellersick Prize, the 7th IEEE Asia-Pacific Outstanding Paper Award, and the 2015 IEEE Industrial Innovation Award for Leadership and Innovation in Next-Generation Cellular Wireless Networks. She is the Co-Chair of the O-RAN Technical Steering Committee and an O-RAN Executive Committee Member, the Chair of FuTURE 5G/6G SIG, the Chair of Wireless AI Alliance Executive Committee, an Executive Board Member of GreenTouch, a Network Operator Council Founding Member of ETSI NFV, and a Steering Board Member and the Vice Chair of WWRF, a Steering Committee Member and the Publication Chair of IEEE 5G and Future Networks Initiatives.



Sunder Ali Khowaja (Senior Member, IEEE) received the Ph.D. degree in industrial information systems engineering from the Hankuk University of Foreign Studies, South Korea. He has worked as a Postdoctoral Research Fellow with the Department of Mechatronics Engineering, Tech University of Korea, Republic of Korea. He is currently serving as an Assistant Professor with the Department of Telecommunication Engineering, Faculty of Engineering Technology, University of Sindh, Pakistan. He had the experience of working with multinational companies as a Network and RF Engineer from 2008 to 2011. He has teaching, research and administrative experience of more than 10 years. He has published more than 50 research articles in national, international journals, and conference proceedings. His research interests include computer vision, self-supervised learning, federated learning, privacy-preservation machine learning, and data analytics. He is the recipient of runner-up for UG2+ Competition (Atmospheric Turbulence Mitigation) at CVPR2022 and second runner-up for UG2+ Competition (Target Coded Restoration Challenge) at CVPR 2023. Furthermore, he has achieved Top ten positions in several of the CVPR challenges from 2022 to 2023, including PBVS Multi-modal Aerial Object Recognition Challenge, PBVS Thermal Image SuperResolution, NTIRE Image SuperResolution Challenge, NTIRE Video SuperResolution Challenge, and NTIRE Image Denoising Challenge. He is also a Regular Reviewer of notable journals, including IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, IEEE INTERNET OF THINGS JOURNAL, IEEE TRANSACTIONS ON SERVICES COMPUTING, IEEE TRANSACTIONS ON MEDICAL IMAGING, *Computers in Industry*, IEEE ACCESS, *Electronic Letters*, *IET Image Processing*, *IET Signal Processing*, *Computer Communications*, *International Journal of Imaging Systems and Technology*, *Multimedia Systems*, *IET Networks*, *SN Applied Sciences*, *Artificial Intelligence Review*, *Computational and Mathematical in Medicine*, *Computers in Human Behavior*, *IET Wireless Sensor Systems*, *Journal of Information Processing Systems*, and *Mathematical Problems in Engineering*. He is also currently serving as an Associate Editor for *PLoS ONE*. In addition, he is serving as a Guest Editor for special issues in IEEE TRANSACTIONS ON CONSUMER ELECTRONICS, *Computers and Electrical Engineering*, *Human-centric Computing and Information Sciences*, *Journal of King Saud University: Computer and Information Sciences*, and *Sustainable Energy Technology and Assessments*. He has also served as a TPC member for workshops in A* Conferences, such as Globecom, Mobicom, and ICDCS.