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EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: APPLYING FOUR D'S OF MACHINE LEARNING TO ADVANCE BIOMETRICS

With the availability of inexpensive biometric sensors, computing power, and memory, it is becoming increasingly clear that biometrics technology will have broader usage, and therefore broader scope of future research in addressing newer challenges and pushing the boundaries. If we perceive of biometrics as a fundamental technology with broad scientific and economic impact, then designing efficient algorithms and systems will require a multidisciplinary effort in signal/image processing, pattern recognition, machine learning, sensor design, embedded systems, and information fusion.

Recent advances in machine learning have seen widespread development of algorithms in four specific areas: **D**eep learning, **D**ictionary learning, **D**omain adaptation, and **D**istance metric learning. While deep learning and dictionary learning algorithms are used for (learned) feature extraction, distance metric learning approaches are utilized for learning good metrics over the input space. On the other hand, domain adaptation refers to the ability of a machine learning algorithm to *adapt* the knowledge learned in previous (source) domain to novel (target) domain. As a consumer of these 4-D paradigms, the likelihood of exploring new avenues of biometrics research is immense.

The objective of this Special Section on "Applying four D's of machine learning to advance biometrics" is to identify recent challenges in biometrics, present the approaches following the 4-D paradigm, and discuss the key results and future research directions. All submitted papers were peer reviewed by expert referees and five outstanding articles, including one invited paper, were accepted for inclusion in this Special Section. The accepted papers reflect the importance of this research paradigm. Since IEEE ACCESS is an open access journal, these papers are freely available to all the readers across the world.

Among many applications, mobile-based biometric systems are gaining significant popularity. While Convolutional Neural Networks (CNN) have shown high accuracies, the time required to perform feature extraction on mobile devices can deter their usage in many applications. Polyak and Wolf, in their invited paper, "Channel-level acceleration of deep face representations", present two novel approaches to reduce the computation requirement of CNNs suited for mobile applications. In the first approach, the authors selectively remove input channels from the computation by eliminating less active channels. The second approach, termed *reduce and reuse*, eliminates entire channels by making use of the redundancy in the network. Experiments on different databases show that with very little reduction in accuracy, approximately 2.5 times runtime improvement can be obtained. This line of research can make the use of deep learning algorithms more feasible for a broader range of applications on mobile devices.

The paper on "Coupled auto-associative neural networks for heterogeneous face recognition" by Riggan et al. presents a deep learning framework for heterogeneous face recognition in which two deep networks are jointly trained. The proposed stacked coupled autoencoder network learns the non-linear cross-model transformation by forcing the hidden units or latent features of two ingredient networks to be as similar as possible. In the process, it is also assured that information from the input is preserved. Experiments are performed on multiple heterogeneous databases, and results and future research directions are discussed in detail.

Humans naturally age, and as we age, there are body-weight variations which are affected by our eating habits, environment, and genetics. These variations can affect automatic face recognition algorithms and this is the focus of the paper by Nagpal et al. titled "Regularized deep learning for face recognition with weight variations". The authors propose a deep learning framework by introducing body-weight aware $l_{2,1}$ norm that can minimize the effect of body-weight variations on face recognition. The proposed framework is applied to both autoencoder and deep Boltzmann machine, and the results on the eWIT database show that the proposed approach improves the overall identification performance.

Video-based face recognition is an important application, particularly in surveillance and law enforcement applications. In "Dictionary-based face and person recognition from unconstrained video", Chen et al. present a video-dictionary based approach which encodes temporal variations along with pose, expression, and illumination variations observed in videos of different subjects. The proposed video-dictionary approach learns the features for both face and body to improve the recognition capabilities. The authors also extend the proposed approach by introducing kernel trick to learn the non-linearities in the data. Experiments on different databases

show that combining face and body cues helps in improving the performance and the proposed approach yields state-of-the-art results on challenging databases.

The final paper in the Special Section presents an interesting application of dictionary learning in detecting plastic surgery alterations to improve the performance of face biometrics. ''Multiple projective dictionary learning to detect plastic surgery for face verification'' by Kohli et al. presents a two-stage approach in which plastic surgery detection is performed in Stage-1 using multiple projective dictionary learning (MPDL). After a pair of gallery and probe images is detected as an instance of *plastic surgery*, Stage-2 of the proposed algorithm verifies the identity of the individual. On a plastic surgery database of 900 subjects, experimental results show around 98% plastic surgery detection accuracy. The results also demonstrate that surgery detection using the proposed algorithm considerably improves the face verification performance.

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MAYANK VATSA
RICHA SINGH
KEVIN BOWYER

MAYANK VATSA (SM'14) received the M.S. and Ph.D. degrees in computer science from West Virginia University, Morgantown, USA, in 2005 and 2008, respectively. He is currently an Associate Professor and AR Krishnaswamy Faculty Research Fellow with the Indraprastha Institute of Information Technology, Delhi, India. He has authored over 150 research papers. His areas of interest are biometrics, image processing, machine learning, and information fusion. He is a member of the Computer Society and the Association for Computing Machinery. He is a recipient of the FAST Award by DST, India. He received several best paper and best poster awards and the NVIDIA Innovation Award 2015. His research has been funded by the UIDAI, DST, and DeitY. He is the Vice President (Publications) of the IEEE Biometrics Council, an Area Editor of the IEEE BIOMETRIC COMPENDIUM, and an Associate Editor of the *Information Fusion Journal* (Elsevier) and the IEEE ACCESS. He was also the Program Committee Co-Chair of the IAPR International Conference on Biometrics 2013 and the International Joint Conference on Biometrics 2014.

RICHA SINGH (SM'14) received the Ph.D. degree in computer science from West Virginia University, Morgantown, USA, in 2008. She is currently an Associate Professor and a TV Mohandas Pai Faculty Research Fellow with the Indraprastha Institute of Information Technology, Delhi, India. She has co-authored over 150 research papers. Her areas of interest are biometrics, pattern recognition, and machine learning. She is a member of the Computer Society and the Association for Computing Machinery. She is a recipient of the FAST Award by DST, India. She received several best paper and best poster awards in international conferences. She was a recipient of the NVIDIA Innovation Award 2015 and the Best Reviewer Award at the IAPR International Conference on Biometrics 2013. Her research has been funded by the UIDAI and DeitY, India. She is also an Editorial Board Member of *Information Fusion* (Elsevier) and the *EURASIP Journal of Image and Vision Processing* (Springer). She serves as the PC Co-Chair of the IEEE International Conference on Biometrics: Theory, Applications, and Systems 2016.

KEVIN BOWYER (F'98) is currently the Schubmehl-Prein Professor of Computer Science and Engineering with the University of Notre Dame and serves as the Chair of the Department. His most recent book is the *Handbook of Iris Recognition*, edited with Dr. M. Burge. His research interests range broadly over computer vision and pattern recognition, including biometrics and data mining. He is a fellow of the International Association for Pattern Recognition for contributions to computer vision, pattern recognition, and biometrics, and a Golden Core Member of the IEEE Computer Society. He received the 2014 Technical Achievement Award from the IEEE Computer Society, with the citation for pioneering contributions to the science and engineering of biometrics. He serves as the General Chair of the 2015 IEEE International Conference on Automatic Face and Gesture Recognition, and the 2015 IEEE International Conference on Biometrics Theory, Applications and Systems. He has served as the Editor-in-Chief of the IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE and the IEEE BIOMETRICS COMPENDIUM. He also serves on the Editorial Board of the IEEE ACCESS.