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EDITORIAL

SPECIAL SECTION

Deep Learning: Theory and Practice

A. CICHOCKI, T. POGGIO, S. OSOWSKI, and V. LEMPITSKY

Recent breakthroughs in the fields of artificial intelligence (AI) and machine learning (ML) have been largely triggered by the emergence of the wide class of the deep neural network (DNN) technology, especially of convolutional neural networks (CNN). DNNs have become a vehicle for a large number of potential applications and commercial ventures in computer vision, early diagnosis of some diseases, drug discovery, biomedical informatics, prediction, natural language processing, recommender systems, robotics, gaming and artificial creativity, to mention but a few. The renaissance of deep neural networks has both created an active frontier of research in machine learning and provided many advantages in a variety of applications, to the extent that the performance of DNNs in multi-class classification and verification tasks can be comparable or even better than what is achievable by humans.

Deep learning methods continue to dominate the field of machine learning, and are now important in many research areas, especially in artificial intelligence. Thanks to the increasing computational power of computers and the development of new architectures of neural networks, research in this area is greatly accelerated.

Deep neural networks, such as convolutional neural networks (CNN) or recurrent long short-term memory (LSTM) networks, have found wide applications in different fields of computer vision and pattern recognition. Examples of such applications include recognition and classification of objects existing in images, image restoration, real-time multi-person pose estimation, computer games, translation, voice generation, music composition, transferring styles from famous paintings, etc. Deep learning was found highly useful in bioengineering, in which we handle the very difficult problems of medical image and signal analysis.

This Special Section of the Bulletin of the Polish Academy of Sciences on Technical Sciences is devoted to theoretical aspects of deep machine learning as well as practical applications in some areas of signal and image processing, particularly in bioengineering.

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It is to focus on recent research on deep learning. The papers comprising the present issue of the Bulletin are grouped into two main categories: theoretical aspects of deep learning and practical applications in bioengineering.

1. Papers devoted to theoretical aspects of deep learning [1–6].

Papers [1, 2] by T. Poggio et al. are devoted to fundamental theoretical questions of deep neural networks, such as “which classes of functions can they approximate effectively?”, “what is the empirical risk landscape?” as well as the most important question about generalization capabilities of deep networks. The problem of the curse of dimensionality in such solutions is also analyzed. The authors consider the cases in which deep networks are guaranteed to avoid the curse of dimensionality. They argue that the key aspect of convolutional networks is the locality at each level of layered signal processing.

Paper [3], co-authored by A. Novikov, M. Trofimov, and I. Oseledets, introduces the so-called exponential machines, serving as a predictor that models the interactions between features of any orders. The main idea is to represent the exponentially large tensor of parameters in a factorized format known as the tensor train. The tensor train format regularizes the model and allows to control the number of underlying parameters. The stochastic Riemannian optimization procedure was developed to train the model.

Paper [4], by V. Lebedev and V. Lempitsky, deals with a very important problem of speeding-up computation in convolutional neural networks, required due to the very large size of such architectures. Several research directions for speeding up CNNs have been presented and discussed. They include tensor decompositions, weight quantization, weight pruning and teacher-student approaches.

Paper [5], co-authored by M. Figurnov, A. Sobolev, and D. Vetrov, presents the probabilistic model with discrete latent variables, which allows to reduce computation time at the learning stage of deep network models, such as ResNet CNNs and LSTMs. The method presented provides the highly desired trade-off between speed and accuracy.

Paper [6], by F. Horn and K.R. Müller, considers the problem of predicting pairwise relations. The novel neural network architecture under the name of similarity encoder is defined. It simultaneously factorizes a given target matrix and learns the mapping to project the data feature vectors onto a similarity-preserving embedding space.

2. Papers presenting different applications of deep learning in bioengineering [7–11].

Paper [7], co-authored by J. Kurek, B. Swiderski, S. Osowski, M. Kruk, and W. Barhoumi, is devoted to recognition of mammogram images. Two approaches are presented and compared: the convolutional neural network versus the classical approach to this recognition problem. Both methods were evaluated on the basis of recognition of normal versus abnormal cases. The experiments have been conducted using 10,168 regions of interest of mammographic images taken from the DDSM database. They have eventually shown the advantage of the CNN approach.

The paper co-authored by Y. Qiu, G.Zhou, Q. Zhao and A. Cichocki [8] presents a comprehensive study of the state-of-the art machine learning methods used in breast cancer diagnosis nowadays. Different methods of feature definition and selection are considered, including deep learning using CNN and autoencoders. Massive comparative results are presented and discussed.

Paper [9], co-authored by Z. Swiderska-Chadaj, T. Markiewicz, J. Gallego, G. Bueno, B. Grala and M. Lorent, is devoted to the segmentation and detection of damaged regions containing certain distortions, deformations, folds or tissue breaks in complete slide images of histological images of brain tumor specimens prepared by means of Ki-67 staining. The proposed technique is based on application of CNN and uses the so-called Unet model to achieve pixel-wise segmentation of these unwanted regions.

Paper [10], co-authored by B. Stasiak, P. Tarasiuk, I. Michalska and A. Tomczyk, presents the solution to the problem of automatic localization of multiple sclerosis (MS) lesions within brain tissue. CNN is used to recognize the lesions in magnetic resonance images (MRI scans) of the patient's brain. To provide additional hints on location of a given clip within the brain structures, some additional anatomical information, indicating the location of ventricles and other structures, has enhanced the results of automatic localization of MS-related plaques.

Paper [11], by J. Jakubowski and J. Chmielińska, aims at developing some detectors of driver fatigue on the basis of face image analysis. A pre-trained AlexNet model of CNN and transfer learning were both used in the investigations. The results obtained from real images of multiple drivers have shown good perspective of application of the method in real life.

Paper [12], by V. Osin, A. Cichocki and E. Burnaev, presents an algorithm based on CNN, to be used for the fusion of multi-spectral data that will consolidate the data from visible and infrared spectral ranges as well as modify the detection algorithms applicable in embedded systems. The results of this study are used in image recognition systems for the next generation of intelligent lighting systems.

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e-mail: a.cichocki@sklotech.ru

Andrzej Cichocki received his M.Sc. (with honors), Ph.D. and Dr.Sc. (habilitation) degrees, all in electrical engineering, from the Warsaw University of Technology, Poland. He worked for several years at the Erlangen-Nürnberg University in Germany as an Alexander von Humboldt Research Fellow and Visiting Professor. In 1995–2018, he was the team leader of the laboratory and the head of the laboratory for Advanced Brain Signal Processing at the RIKEN Brain Science Institute in Japan. Under the guidance of Professor Cichocki, the new "Tensor Networks and Deep Learning for Applications in Data Mining" Laboratory is being established at the SKOLTECH University, supported by the Ministry of Education and Science of the Russian Federation under grant 14.756.31.0001. The mission of the Laboratory is to perform cutting-edge innovative research on the design and analysis of deep neural networks, tensor networks and multiway component analysis for biomedical applications. He is among the most cited Polish computer scientists and is or has been the associate editor of top journals in signal processing and neural networks.

e-mail: sto@iem.pw.edu.pl

Stanisław Osowski received his M.Sc., Ph.D. and D.Sc. degrees from the Warsaw University of Technology, Poland, in 1972, 1975, and 1981, respectively. All of the above were in electrical engineering. Currently, he is a Professor of electrical engineering at the Institute of the Theory of Electrical Engineering and Electrical Measurements of the same university and at the Military University of Technology in Warsaw. His research and teaching interests are in the areas of neural networks, data mining and their applications in various areas of biomedical engineering. He is an author or co-author of numerous scientific papers and books.

e-mail: lempitsky@skoltech.ru

Victor Lempitsky is a lab leader at the Samsung AI Center in Moscow and an Associate Professor at Skoltech (Skolkovo Institute of Science and Technology), where he heads the Computer Vision Group. He has received his Ph.D. from Moscow State University (2007) and has held research positions at Microsoft Research, University of Oxford and Yandex. His research interests include the areas of computer vision and deep learning.

e-mail: tp@csail.mit.edu

Tomaso A. Poggio is a Eugene McDermott Professor at the Department of Brain & Cognitive Sciences at MIT and the director of the new NSF Center for Brains, Minds and Machines at MIT, of which MIT and Harvard are the main member Institutions. He is a member of both the MIT Computer Science and Artificial Intelligence Laboratory and of the McGovern Brain Institute. He is also an honorary member of the Neuroscience Research Program, a member of the American Academy of Arts and Sciences, a Founding Fellow of AAAI, a founding member of the McGovern Institute for Brain Research and a Core founding scientific advisor of the MIT Quest for Intelligence. Among other honors, he has received the Laurea Honoris Causa from the University of Pavia for the Volta Bicentennial, the 2003 Gabor Award, the 2009 Okawa Prize, the AAAS Fellowship and the 2014 Swartz Prize for Theoretical and Computational Neuroscience. He is one of the most cited computational scientists with contributions ranging from biophysical and behavioral studies of the visual system to computational analyses of vision and learning in humans and machines. His research has always been interdisciplinary, bridging brains and computers. It is now focused on the mathematics of deep learning and on computational neuroscience of the visual cortex. Former Corporate Fellow of Thinking Machines Corporation and former director of PHZ Capital Partners, Inc., he also acted as a director of Mobileye and was involved in starting as well as investing several other high tech companies, including Arris Pharmaceutical, nFX, Imagen, Digital Persona and Deep Mind. His Ph.D. students and post-docs include some of today's leaders in science and in engineering of intelligence. They are *inter alia*: Christof Koch (President and Chief Scientific Officer, Allen Institute), Amnon Shashua (CTO and founder, Mobileye) and Demis Hassabis (CEO and founder, Deep Mind).