Exploring Deep Learning for Efficient and Reliable Mobile Sensing





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Smart devices equipped with a rich set of sensors, such as smartphones and wearables, are enabling an ever-increasing number of mobile applications, ranging from user behavior perception such as gesture recognition and health monitoring to context inference such as driving detection and hazard warning. However, reliably inferring high-value user behavior and context information from noisy and highly heterogeneous sensor data using mobile devices remains an open issue. To combat against the constraints of a mobile device, one conventional approach is to upload raw sensor data to the cloud and run complex inference algorithms remotely. This leads to inefficiency in terms of network overhead and large latency for mobile applications. Recently, deep learning techniques have made significant breakthroughs in achieving state-of-art inference performance in a variety of applications such as computer vision and natural language processing. In general, data modeling challenges found in mobile sensing can often be seen in deep-learning-based inference. Promisingly, with the ever-increasing computational capability of today's smart devices as well as the new edge computing architecture where data processing is performed at the edge of the network, it is possible to apply the latest developments in deep learning to mobile sensing from the cloud toward the edge and/or mobile devices. However, this presents a set of new challenges, such as computational overhead associated with deep learning, training models requiring large data sets, mobile devices being short of battery power, etc. These challenges need to be carefully investigated in the near future before robust mobile inference can be fulfilled at no efficiency cost.

This special issue aims to present recent advanced research studies for exploring deep learning for mobile sensing. It includes nine technical contributions from leading researchers in the area of mobile computing. The first article, entitled "Deep Learning Based Inference of Private Information Using Embedded Sensors in Smart Devices" by Liang, Cai, Yu, Han, and Li, shows that seemingly innocuous sensor data could cause serious privacy issues when using deep learning algorithms to infer a user's app usage habits. The next article, co-authored by Feng, Fu, Dong, Guo and Li, is entitled "Multistage and Elastic Spam Detection in Mobile Social Networks through Deep Learning". It focuses on online spam detection in mobile social networks utilizing deep learning and edge computing techniques. Real-world mobile social network traces collected from Sina Weibo are collected for analysis and evaluation. The third article, entitled "A Dropconnect Deep Computation Model for Highly Heterogeneous Data Feature Learning in Mobile Sensing Network" by Zhang, Yang, Chen, and Li, focuses on a deep computation model for small heterogeneous data sets on mobile devices. The fourth article, co-authored by Peng, Gao, Li, Xiao, and Qian, studies a new deep learning framework to conduct real-time road safety prediction. The fifth article, entitled "Reinforcement Learning-based Content-Centric Services in Mobile Sensing" by Gai and Qiu, discusses how to utilize the mechanism of reinforcement learning to achieve optimal resource allocation through a self-learning process in resource outsourcing. The next article, entitled "Urban Traffic Prediction from Mobility Data Using Deep Learning: An Outlook" by Liu, Li, Wu and Li, discusses the practice of using deep learning on predictions of traffic information on a large large scale and points out two future research directions to improve the accuracy and efficiency of such predictions. The seventh article, co-authored by Ren, Zhang, Xiao, Zhou, Li and Yang, proposes a very appealing application, called Word-Fi, which uses deep learning and wireless backscattering to infer the handwriting of a user. A high accuracy of above 90 percent is achieved. The eighth article, entitled "Robust Mobile Crowd Sensing: When Deep Learning Meets Edge Computing" by Zhou, Liao, Gu, Mumtaz, Saidul Huq and Rodriguez, introduces a framework for robust mobile crowd sensing, which integrates deep learning based error detection and mobile edge computing. The last (but not least) article, "Privacy in Neural Network Learning: Threats and Countermeasures", is co-authored by Chang and Li. It reveals the privacy issues in neural network (NN) learning. More specifically, the privacy threats during NN training are identified and privacy-preserving training schemes are also presented. In addition, the privacy of prediction requests is also considered and privacy-preserving protocols for NN prediction are discussed.

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Biographies

Hongzi Zhu received his Ph.D. degree in computer science from Shanghai Jiao Tong University in 2009. He was a post-doctoral fellow in the Department of Computer Science and Engineering at Hong Kong University of Science and Technology and the Department of Electrical and Computer Engineering at the University of Waterloo in 2009 and 2010, respectively. He is now an associate professor in the Department of Computer Science and Engineering at Shanghai Jiao Tong University. His research interests include vehicular networks, wireless networks and mobile computing. He received the Best Paper Award from IEEE Globecom 2016. He currently serves as the associate editor for several journals, including *IEEE Transactions on Vehicular Technology* (TVT) and *Peer-to-Peer Networking and Applications* (Springer).

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Kaoru Ota received her M.S. degree from Oklahoma State University, USA in 2008, and B.S. and Ph.D. degrees from The University of Aizu, Japan in 2006 and 2012, respectively. She is currently an assistant professor with the Department of Information and Electronic Engineering, Muroran Institute of Technology, Japan. From March 2010 to March 2011 she was a visiting scholar at the University of Waterloo, Canada. Her research interests include wireless networks, cloud computing, and cyber-physical systems. She has received best paper awards from ICA3PP 2014, GPC 2015, IEEE DASC 2015, IEEE VTC 2016-Fall, FCST 2017, 2017 IET Communications Premium Award and IEEE ComSoc CSIM Best Conference Paper Award 2018. She is an editor of *IEEE Transactions on Vehicular Technology* (TVT), *IEEE Communications Letters*, *Peer-to-Peer Networking and Applications* (Springer), *Ad Hoc & Sensor Wireless Networks*, as well as a guest editor for *ACM Transactions on Multimedia Computing*, *Communications and Applications* (leading), *IEEE Internet of Things Journal*, *IEEE Communications Magazine*, *IEEE Network*, *IEEE Wireless Communications*, *IEEE Access*, *IEICE Transactions on Information and Systems*, and *Ad Hoc & Sensor Wireless Networks* (Old City Publishing). She is the recipient of IEEE TCSC Early Career Award 2017.