AI-driven soldier technology wins praise from engineering society

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Soldiers evaluate the US Army's Tactical Computing Environment and other mission command technologies during the Expeditionary Command Post Science and Technology Field-Based Risk Reduction Exercise. Credit: Kathryn Bailey, CERDEC CP&I Directorate

The Institute of Electrical and Electronics Engineers Communications

Society recognized an Army researcher and collaborators their work on artificially intelligent techniques that will enhance Soldiers' situational awareness in the multi-domain operating environment.

Dr. Kevin Chan, researcher for the U.S. Army Combat Capabilities Development Command, known as DEVCOM, Army Research Laboratory, and collaborators from the IBM T. J. Watson Research Center, Imperial College London and Pennsylvania State University earned the IEEE's Leonard G. Abraham prize for for their paper, Adaptive Federated Learning in Resource Constrained Edge Computing Systems. The researchers published their findings in the IEEE Journal on Selected Areas in Communications.

According to the researchers, the collaborative effort was possible because of the lab's Distributed Analytics and Information Science International Technology Alliance. The program seeks to develop the fundamental underpinning research required to enable secure, dynamic and semantically-aware distributed analytics for deriving situational understanding in coalition operations.

This research further extends the capability and applicability of federated learning, a term initially coined by Google.

"A critical use case of federated learning is in coalition operations, where data sharing may be proscribed by policy constraints, but model sharing may be allowed," said Dr. Ananthram Swami, DEVCOM ARL fellow and senior research scientist. "Further, paucity of data in Army-relevant scenarios makes such model sharing important to improve prediction accuracy."

The paper and research address several important problems in federated learning, or FL, for the first time, including training optimization under resource constraints, convergence of FL with non-identically-distributed

data distribution, and technique validation by implementation using real-world edge devices. According to the society, the researchers paper demonstrated high quality, originality, utility, timeliness and clarity of presentation.

"The fact that this paper is able to propose a solution that jointly addresses all these issues in a coherent manner makes it a very valuable scientific contribution," said Dr. Shiqiang Wang, researcher at the IBM Thomas J. Watson Research Center.

Federated learning enables mobile devices to collaboratively learn a shared prediction model while keeping all the training data on the device, decoupling the ability to do machine learning from the need to store the data in the cloud, Chan said.

"The contribution of our research was to understand how we could perform federated learning at the tactical edge," Chan said. "This work studies how we can best learn on large sets of low-powered devices connected over resource constrained networks".

The Army is moving toward using artificial intelligence and machine learning in all aspects of operations, particularly in tactical network settings, where large amounts of data are generated at the edge and must be understood, and despite limitations of computing and network resources, must be used to support a broad range of operations, Chan said.

Future outcomes of this research will enable the Soldier to establish and maintain situational awareness more rapidly leveraging information from many devices, he said

"Analytic services such as image classification and pattern recognition are very important for supporting military operations," Wang said.

These services require the use of a large volume of data, often owned by different entities and available at dispersed locations, to train the analytic models for various tasks, he said. Such model training encounters the following major constraints in tactical environments:

- Data owners may prefer to preserve data privacy by not sharing their data with others
- Limited availability of communications, computational and other resources often prohibit transfer of all data to a central server for the training process

The team tackled the technical challenge of distributed learning subject to the data privacy and limited resource constraints. Specifically, they developed resource-efficient federated learning to train analytic models where the private data remains local on the network-edge nodes and only model parameters are shared between different nodes.

According to the researchers, the new method includes local model updates at the edge nodes and global parameter aggregations by a central server. The technique aims to coordinate these different FL operations to achieve the most efficient model training subject to the constraints.

"In terms of implications for defense applications, this new technology enables distributed training or adaptation of analytics models in resource-constrained environments, to allow coalition partners (or military units) to help each other learn similar tasks without the need of sharing their sensitive data due to privacy considerations or lack of communication resources," said Professor Kin Leung, Electrical and Electronic Engineering, and Computing Departments at Imperial College London. "The new approach provides the cutting-edge capability over our adversaries."

Federated learning is a must-have if coalition forces want to combine the

insights from their independent data to build better AI models, said Dr. Dinesh Verma, IBM fellow leading the team working in the area of Distributed AI.

"Such types of sharing can be very difficult at the tactical edge due to limited bandwidth," Verma said. "The innovations proposed by this research address many of these difficulties, making such sharing feasible in coalition tactical networks. The technology has applicability beyond tactical networks—in any environment where multiple organizations share insights in a bandwidth limited environment including automotive, manufacturing, forestry and mining industries."

The team will accept the award at a virtual presentation at the IEEE International Conference on Communications June 15.

"It is an honor to be recognized by the IEEE Communications Society for our successful research and its contribution to the communications and networks research community," Chan said. "It is a greater honor to be awarded this prize with several institutions with whom ARL has extensively collaborated. The collaborators are also researchers with whom I have personally worked with for many years, so it is great to be recognized as a team."

This paper has established an important foundation of FL for the resource-constrained edge, Wang said.

"The proposed technique is critical for future Internet of Things, edge computing, and cellular (5G, 6G and beyond) systems, where many applications will be AI-driven, devices will be equipped with computational and storage capabilities, and data privacy will be increasingly important," Wang said. "In fact, the paper has influenced many other researchers, as reflected by over 400 Google Scholar citations since its publication in 2019.

More information: Shiqiang Wang et al, Adaptive Federated Learning in Resource Constrained Edge Computing Systems, *IEEE Journal on Selected Areas in Communications* (2019). DOI: 10.1109/JSAC.2019.2904348