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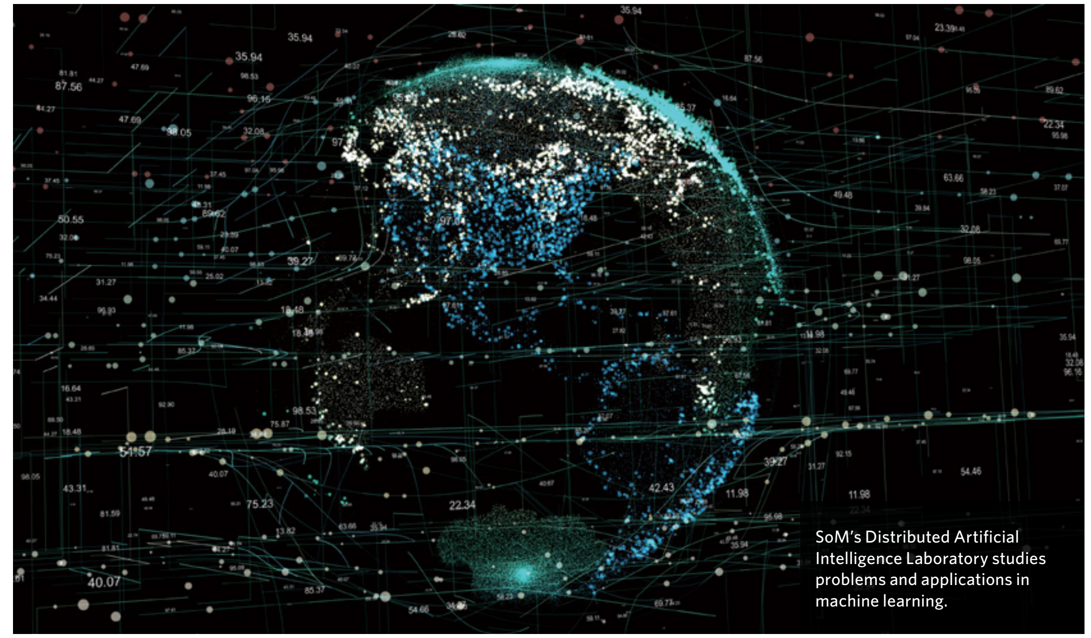
Strengthening links in the discovery chain

A young mathematical school in Beijing is contributing to REAL-WORLD SOLUTIONS through AI innovations.

SoM's Blockchain Laboratory has devised theoretical innovations for blockchain architecture.



SoM's Distributed Artificial Intelligence Laboratory studies problems and applications in machine learning.

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Pushing the boundaries of emerging fields is central to the academic ambition of the School of Mathematics (SoM) at Renmin University of China.

The history of SoM can be traced back to its beginning as a department of economic information management in 1978. It became a school in 2018, and is now home to the departments of mathematics and applied mathematics, information and computation sciences, financial mathematics and computation.

Its dean, Zhiyong Zheng, says SoM's priority in the next five years is to integrate fundamental studies in mathematics with the expanding fields of AI and blockchain, driven by a growing global faculty.

An expert in analytic and algebraic number theories, Zheng is also the director of the Engineering Research Center of Financial Computing and Digital Engineering (ERC-FCDE). A ministerial-level platform with support from the Ministry of Education, it houses three affiliated laboratories for applied mathematics.

Comprehensive look at machine learning

Dong Shen, the director of the Distributed Artificial Intelligence Laboratory (DAIL), leads investigations into machine learning control (MLC), which aims to mathematically describe the principles of human learning. In systems which perform repetitive tasks, iterative learning control (ILC) gradually reduces tracking errors to enhance performance through iteration, learning from accumulated information.

In this area, active type refers to objective-driven, human-led reduction of data quantity and quality, such as sampling and quantization. Passive type refers to practical system limitations during data collection, storage, transmission, and processing, which ranges from data dropouts, delays to limited

Zhiyong Zheng, dean of SoM

bandwidth. Incomplete information can interrupt both passive and active types, for which Shen has extensively published targeted ILC strategies.

One of the most challenging constraints is packet loss, which occurs when one or more packets of data fail to reach their destination across a computer network. Shen developed models of finite-length random sequences, and further expanded to convergence analyses and algorithm designs for complex coupling of multiple constraints.

To ease data quantization problems in ILC, he designed a framework to minimize tracking errors through algorithm encoding and decoding mechanisms. He also created a new composite energy function (CEF) for proving asymptotical convergence for variable trial length learning, which describes how fast the sequence could arrive at an optimal solution.

Based on the theoretical analysis of support vector machines, which are supervised learning models, Shen's team also proposed useful instance-based learning algorithms, known as kernels, for real-world applications. Data from single-cell genomics, for example, is notably challenging because it is multi-dimensional and nonlinear, with a low signal-to-noise ratio. Drawing from theories of statistics, matrix analysis, and mathematical optimization, Shen's team has come up with a holistic approach including data

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imputation, heterogeneity analysis, and nonlinear kernel functions for mining and calculating biological data.

"Our research can lead to unprecedented opportunities for bioinformatics researchers in examining complex diseases, such as outcome prediction for cancer patients," says Shen.

New insights for blockchain and risk control

In contrast to information technology architecture that is predominantly centralized, blockchain technology has emerged as a decentralized alternative which can alleviate security risk and lower maintenance cost. Rapidly transforming everyday life, especially in finance, blockchain is studied at ERC-FCDE's Blockchain Laboratory (BL), led by Yong Yuan. He is the author of *Blockchain Theory and Methods*, the first theoretical monograph of its kind in China, published in 2019. Together with his team, Yuan has authored more than 200 peer-reviewed papers.

Their theoretical innovations include the dissection of blockchain architecture in six layers: data, network, consensus, incentive, contract, and application. Starting with data structure as the storage tool, this frames blockchain as a distributed ledger, or a record of data that is maintained by self-interested 'miners' who can propose their own version of a ledger, without having to go through a centralized bank or government. Miners, however, solve computationally tough problems, in order to compete to win block rewards to become a consensus leader.

A consensus layer with agreed protocols is therefore needed for the ledger to function, while the incentive layer integrates miners' economic considerations, and the contract layer encapsulates the system's programmability with scripts and algorithms.

In response to system inefficiency, Yuan proposed proof of credit (PoC), which is a fairer and more efficient alternative to other consensus algorithms, including the energy-heavy proof of work (PoW) which is used by Bitcoin. Fairness refers to the evaluation of consensus leader. PoW requires all miners to compete, with the leader determined by the power and quantity of its hardware devices. PoC, however, selects a leader based on the credit they have staked, quantifying whether the miner's activity is beneficial to the system. Yuan also introduced a variety of incentive distribution strategies, and effective transaction pricing mechanisms via big data.

His contributions take a bottom-up design approach to enrich efficiency and incentive compatibility, proposing solutions to optimize the 'Pareto' frontier for the DCS (Decentralized-Consistent-Scale) trilemma. This refers to security, scalability, and decentralization, which are crucial factors traditionally deemed impossible to achieve in one blockchain system. These research findings have accelerated blockchain knowledge.

Supported by theoretical discoveries at DAIL and BL, a Financial Risk Control Laboratory at the SoM uses various AI technologies, seeking to prevent system-wide financial failures.

A recent highlight of their work includes an artificial intelligence algorithm to find potential systemic risks for quantitative finance, and gradually build a risk prediction and assessment model for the financial market.

"Our platforms are going to make insightful contributions in distributed machine learning, blockchain, and applications in financial risk control," says Zheng. ■

http://math.ruc.edu.cn/
+86-10-62515886
mathruc@ruc.edu.cn

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