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FedCOT: Personalized Federated Transfer Learning With Conditional Optimal Transport for Manufacturing Predictive Modeling

Effective predictive modeling in large-scale manufacturing is hampered by the isolated and limited data from individual organizations, collected from costly experiments and various inspections. Collaboration across organizations can handle these limitations, but it faces two main challenges: privacy concerns over organizations and heterogeneous features from varied sensing and inspection capabilities. Federated learning (FL) offers a solution by allowing organizations to collaboratively train a predictive model without sharing raw data, but standard FL struggles with the problem of feature heterogeneity. To address these challenges, we propose a personalized federated transfer learning framework with conditional optimal transport (FedCOT). FedCOT enables "target"organizations with limited features to benefit from "source"organizations with sufficient features in prediction performance while keeping data privacy through a central server. Each organization learns a personalized encoder-regressor structure by alternating optimization: the encoder maps heterogeneous inputs into a shared latent space, and the regressor predicts responses from the latent representations. Target organizations align their latent representations'structure and corresponding responses with the source organizations'information via COT. We evaluate FedCOT through simulations and a manufacturing case study on fatigue life prediction of additive-manufactured parts. Our case study demonstrates that FedCOT achieves the latent space where target organizations are highly aligned with source organizations, leading to a significant 34.99% improvement in prediction performance over the baseline method. Additionally, we provide theoretical guarantees on OT gradients and predictive consistency.

Special/ Invited session

Invited QSR session

Classification

Both methodology and application

Keywords

Federated learning, feature heterogeneity, additive manufacturing.

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