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Personalized Models and Optimization in Federated Learning

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Abstract

The rapid increase in data generation, combined with the impracticality of centralizing large-scale datasets and the growing complexity of machine learning tasks, has driven the development of distributed learning techniques. Among these, Federated Learning (FL) has gained significant attention due to its privacy-preserving approach, where multiple clients collaboratively train a global model without sharing their local data. However, FL faces several key challenges, including data heterogeneity, high computational costs, and communication inefficiencies. These issues become more pronounced in real-world scenarios where client data distributions are non-IID, computational resources are limited, and communication is constrained.

This thesis addresses these challenges through the development of efficient algorithms for Personalized Federated Learning (pFL) and Constrained Federated Learning. The proposed approaches are designed to handle heterogeneous data, minimize computational overhead, and reduce communication costs while maintaining strong theoretical guarantees.

Specifically, the thesis introduces three key contributions:

(1) PFLMF algorithm a novel pFL formulation based on low-rank matrix optimization, leveraging Burer-Monteiro factorization to enable personalization without relying on predefined distance metrics.
(2) PERMFL algorithm, an algorithm for multi-tier pFL that introduces personalized decision variables for both teams and individual devices, enabling efficient optimization in scenarios with hierarchical client structures.
(3) FedFW algorithm, a projection-free algorithm for constrained FL, which emphasizes low computational cost, privacy preservation, and communication efficiency through sparse signal exchanges.

By addressing critical issues in FL, such as data heterogeneity, computation costs, and communication bottlenecks, the proposed algorithms advance the field of Federated Learning, providing robust and scalable solutions for real-world applications.

Keywords
Distributed Learning, Personalized Federated Learning, Optimization in Machine Learning

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