

The Right to be Forgotten in Federated Learning: An Efficient Realization with Rapid Retraining

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Abstract—In Machine Learning, the emergence of the right to be forgotten gave birth to a paradigm named *machine unlearning*, which enables data holders to proactively erase their data from a trained model. Existing machine unlearning techniques focus on centralized training, where access to all holders’ training data is a must for the server to conduct the unlearning process. It remains largely underexplored about how to achieve unlearning when full access to all training data becomes unavailable. One noteworthy example is Federated Learning (FL), where each participating data holder trains locally, without sharing their training data to the central server. In this paper, we investigate the problem of machine unlearning in FL systems. We start with a formal definition of the unlearning problem in FL and propose a rapid retraining approach to fully erase data samples from a trained FL model. The resulting design allows data holders to jointly conduct the unlearning process efficiently while keeping their training data locally. Our formal convergence and complexity analysis demonstrate that our design can preserve model utility with high efficiency. Extensive evaluations on four real-world datasets illustrate the effectiveness and performance of our proposed realization.

I. INTRODUCTION

The paradigm of “Machine Unlearning” [1] has attracted much attention recently. It has emerged from “the right to be forgotten” [2], where individuals should be entitled to the right to have their private data removed from public directories. This regulated requirement has also set off a privacy-aware technology reform in the context of Machine Learning. From a high-level point of view, the techniques of machine unlearning enable data holders to proactively erase their data from a trained model that memorizes the data. Most of the existing machine unlearning techniques focus on the centralized setting [3]–[10], where all the training data samples are collected to a server, and later specific samples are requested to be erased via unlearning. However, this setting can be somewhat limited in practice because not all data holders are willing to share data for training due to increasing privacy concerns.

In this paper, we investigate the problem of machine unlearning in a more practical scenario, where data holders are collaboratively performing training and unlearning without sharing raw data. In particular, we target Federated Learning (FL) [11]–[17], a widely adopted privacy-aware collaborative

learning framework. In FL, data holders train a model from their local data samples, and the server only aggregates data holders’ local model updates for data privacy considerations [18]. Despite the above benefit, not allowing the sharing of raw data also poses unique challenges for unlearning in FL.

To erase data samples from a trained FL model, a straightforward approach is to simply train a new model from scratch on the remaining dataset (i.e., excluding the samples that need to be erased) following the original training procedure of FL. However, this approach would be neither practical nor economical for real-world models that are usually trained for weeks from massive training samples. Existing studies on centralized machine unlearning [5]–[8] are not directly applicable because they have to access the raw data during unlearning, which is prohibitive in FL in the first place. Very recently, Liu *et al.* [19] proposed an approach called *FedEraser* that aims to address this problem in FL. Unfortunately, this approach has two drawbacks. First, *FedEraser* only initiates the unlearning algorithm among the clients that request data removal. Namely, other clients’ models still hold the contributions of the data to be removed, which will later be aggregated in a global model. Second, their proposed algorithm utilizes the latest rounds of local model updates to approximate the current unlearned model update. However, the data samples to be removed can be used for training from the very beginning, and the utilized model updates may still consist of the trace of those samples.

Erasing data samples from a trained FL model is non-trivial. To better understand the problem, we first identify two unique challenges in the context of FL as follows.

(C1.) Training is interactive. In FL, the client holds data locally and iteratively exchanges model updates with the server to learn a shared global model. In this context, it is challenging for the central server to erase the contribution of the client data to the model. The key reason is that the client continuously shares the knowledge learned from the local dataset with other clients via model aggregation.

(C2.) Training is incremental. Training in FL is also an incremental procedure in which any given local update reflects all previous updates that occurred on the client. Suppose the global model is updated based on the local model updates that specific clients generate at a particular training round. In that case, all subsequent model updates will implicitly relate to the model updates of these clients.

The authors have provided public access to their code and data at github.com/yiliu247/federated-unlearning.

The Forgotten Art Of Learning

Katrin Zwirgmaier



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