Learning from Imperfect Data: Incremental Learning and Few-shot Learning

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My research goal is to endow artificial intelligence systems with **few-shot** and **continual learning** abilities, i.e., learning **efficiently** on **limited labeled data** and **continual data streams**. In pursuit of this goal, I build my research based on the key idea, **learning to learn**, i.e., using **advanced learning and optimization techniques** to design data-driven methods to **dynamically adapt** the key elements in artificial intelligence algorithms, e.g., network structures, essential hyperparameters, and representative data. I believe that the adaptive and dynamic design will significantly improve the capability of AI systems under limited data and continual data streams.

My research focused on the following three perspectives.

For **continual learning**, I studied how to overcome **catastrophic forgetting** by **learning to optimize exemplar data**, **neural network structures**, and **essential hyperparameters**. Specifically, I proposed a novel training framework by leveraging **bilevel optimization** to **optimize a set of synthesized exemplar data** to recall the old knowledge (Liu et al. 2020). I developed a **generic network architecture** that learns to combine high-**stability** and high-**plasticity** neural network blocks (Liu, Schiele, and Sun 2021a). I introduced a learning strategy that **optimizes the essential hyperparameters** dynamically in each incremental phase (Liu, Schiele, and Sun 2021b; Liu et al. 2023a, 2024). The key technique is to utilize **reinforcement learning** and **online learning**.

For **few-shot learning**, I studied how to tackle the **overfitting** problem by **learning to transfer knowledge**, **ensemble deep models**, and **learn with unlabeled data**. I designed a **meta-transfer learning** framework that allows us to leverage the **transferrable** pattern learned from existing large-scale tasks using meta learning (Sun et al. 2019, 2022). I introduced a method that learns to **ensemble deep models** to reduce the model uncertainty in few-shot learning (Liu, Schiele, and Sun 2020). The key technique is **ensemble modeling** and **Bayesian optimization**.

For **applications**, I studied how to overcome **forgetting** in real-world tasks, e.g., **object detection** and **medical imaging**. Specifically, I designed a new method for transformer-based continual object detection which enables effective usage of **knowledge distillation** and **exemplar replay** (Liu et al. 2023b). I proposed a method for continual abdominal multi-organ and tumor segmentation. The key technique is to use **pseudo labeling** and **contrastive language–image pretraining (CLIP)** embeddings (Zhang et al. 2023).

My research has brought broader impacts to both academia and industry. My first-author (equal contribution) work on few-shot learning (Sun et al. 2019) is listed as one of the **Top 100 most cited CVPR papers over the last five years (2024)** by Google Scholar Metric and has been **cited more than 1,600 times**.

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