FIRM: Federated Image Reconstruction Using Multimodal Tomographic Data

Scientific Achievement

- Developed **FIRM**, a projection-free, federated algorithm for solving large-scale **multimodal tomographic inverse problems** with global physical coupling constraints.
- Ked advances:
  - Physics-informed multimodal modeling.
  - Projection-free federated constrained optimization.
  - A quadratic-penalty interpretation with sublinear convergence guarantees.

Significance and Impact

- Enables decentralized multimodal reconstruction without transferring raw experimental data, reducing communication and storage burdens.
- 52× speedup over projection-based federated methods.
- Scalable to large synchrotron datasets.
- Improved reconstruction quality under multimodal integration.
- Supports DOE facilities by enabling efficient, privacy-preserving, distributed scientific imaging.

Technical Approach

- Formulate multimodal tomography as a convex constrained optimization problem.
- Replace expensive projection steps with lightweight vector operations of O(n) complexity, where n is the dimension of variables.
- Interpret the method as a quadratic-penalty scheme with geometric penalty updates and provable convergence guarantees.

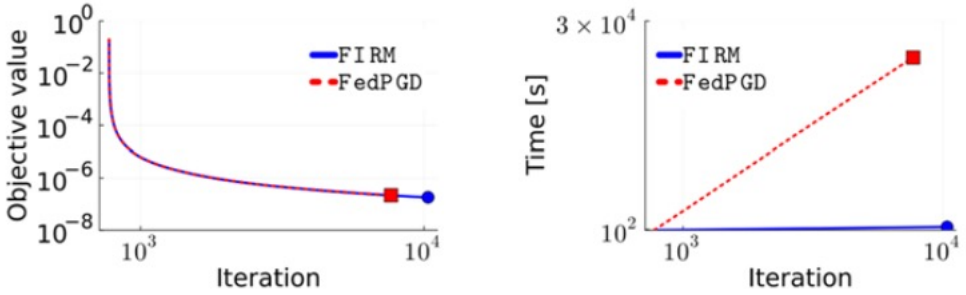

Figure 1. *The proposed FIRM achieves significantly lower computational time than the projection-based FedPGD, while attaining comparable objective values.*

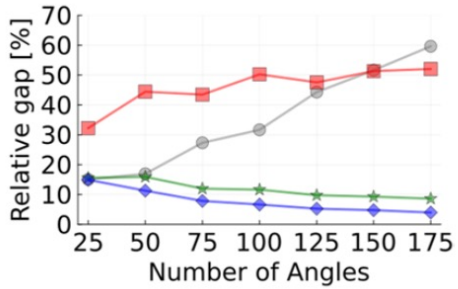

Figure 2. *The effectiveness of incorporating multimodality is quantified by the relative gap; a positive value indicates that multimodal integration yields a reconstruction closer to the ground truth.*

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