Hyperkahler AI–Quantum Integration Stack

Technical Brief for Los Alamos National Laboratory

This document outlines a proposed Hyperkahler manifold–based AI and quantum computation framework, developed for compatibility with Colab and potential integration into Los Alamos National Laboratory (LANL) research programs. The Hyperkahler stack merges quaternionic and complex geometrical structures with deep learning and quantum hybrid simulation. It features an autoencoder architecture inspired by Hyperkahler geometry, enabling representations in quaternionic latent spaces that can preserve rotational symmetries and energy constraints often lost in Euclidean embeddings. Key characteristics: - **Mathematical Foundation:** Built on Hyperkahler geometry (a 4n-dimensional manifold with triple complex structures satisfying quaternionic relations). - **AI Component:** Quaternionic autoencoder structure implemented in PyTorch. - **Quantum Hybrid Layer:** PennyLane variational quantum circuit consuming latent quaternionic embeddings. - **Visualization:** Matplotlib-based 2D latent manifold and reconstruction plots. Applications relevant to LANL: 1. **Quantum algorithm optimization:** Use of quaternionic embeddings to stabilize training of variational quantum algorithms and mitigate barren plateaus. 2. **Materials and condensed matter simulation:** Surrogate PDE modeling through quaternionic manifold representations. 3. **Hybrid HPC-AI architectures:** Lightweight PyTorch modules easily ported to SLURM-based systems or cloud environments. Deliverables included: - Three executable notebooks and equivalent raw `.py` scripts for local or Colab execution. - Readme with dependencies and usage instructions. - This technical summary PDF suitable for internal review or program proposal inclusion. The stack supports rapid iteration and theoretical extensions toward quaternionic kernels, Hyperkahler variational principles, and multi-manifold learning frameworks.

Prepared by: Michael Listrom

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