AI–Quantum Hybrid Diagnostic Systems for Multi-Modal Biomedical Imaging

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***Abstract*—Multi-modal biomedical imaging has become central to modern diagnostics, offering complementary anatomical, functional, and molecular information through modalities such as MRI, CT, PET, ultrasound, and optical imaging. Yet integrating these heterogeneous datasets remains computationally demanding due to differences in spatial resolution, noise profiles, acquisition dynamics, and high-dimensional feature distributions. This paper investigates AI–quantum hybrid diagnostic systems as an emerging paradigm for multimodal image fusion, reconstruction, and disease classification. By combining deep learning architectures with quantum-enhanced algorithms—including variational quantum circuits, quantum feature encoders, and quantum kernel methods—the hybrid framework aims to accelerate image processing, improve cross-modal consistency, and enhance diagnostic precision. The analysis highlights advancements in quantum-accelerated denoising, multi-modal registration, probabilistic inference, and high-dimensional pattern recognition. It also evaluates workflow integration challenges, such as NISQ-era noise, hardware scalability, and clinical interpretability. Overall, AI–quantum hybrid systems represent a promising frontier in medical imaging, offering potential improvements in speed, sensitivity, and personalized diagnostic accuracy.**

Biomedical imaging plays a fundamental role in clinical diagnosis, treatment planning, and disease monitoring. Modern healthcare increasingly relies not on a single modality but on the combined interpretation of multiple imaging sources—MRI for soft-tissue contrast, CT for structural detail, PET for metabolic activity, ultrasound for real-time functional assessment, and optical modalities for cellular and molecular insights [1]. Integrating this diversity of data enables clinicians to obtain a more comprehensive view of pathology, yet achieving robust multimodal fusion remains an unresolved computational challenge. Differences in imaging physics, noise characteristics, temporal acquisition patterns, and spatial resolution produce heterogeneous datasets that are difficult to process and interpret using classical approaches alone [4].

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Artificial intelligence has improved multimodal imaging through deep learning models capable of feature extraction, denoising, segmentation, and predictive analysis. However, as imaging datasets expand in volume and complexity, even advanced AI architectures face limitations in handling high-dimensional correlations, non-linear interactions, and the combinatorial search spaces involved in image fusion and diagnostic decision-making [8]. Quantum computing, with its ability to represent and manipulate

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