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Quantum Reservoir Computing and Principal Component Analysis for Sustainable High-Performance Search: A New Paradigm for Digital Energy Efficiency

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As digital economies scale, the hidden environmental cost of data processing—especially from AI and search engines—has become a growing concern. Search engines like Google and AI models such as Meta AI consume hundreds of kilowatt-hours (kWh) daily; in 2024, Google disclosed that each AI search can consume up to 3 watt-hours, which, at scale, parallels the energy of running a home microwave for 20–30 seconds per query. These figures point to a pressing need to rethink our computational architectures.

We propose a novel hybrid model that combines Quantum Reservoir Computing (QRC) with Principal Component Analysis (PCA) as a means to reduce computational load while maintaining high-performance intelligence. This approach leverages quantum dynamics for memory-rich processing while applying PCA to filter and compress high-dimensional outputs, minimizing redundancy and noise. The integration is particularly designed for High-Performance Computing (HPC) tasks such as indexing, ranking, and personalization within large-scale search engines.

Previous research in QRC has highlighted its potential for temporal processing, but it remains underutilized in real-world, energy-intensive infrastructures. Most prior work applies QRC in small-scale simulations without dimensionality reduction or power profiling. Our method introduces PCA post-processing as a compression lens—a missing piece in current quantum reservoir computing literature.

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