Quantum Generative Seed Compression (QGSC)

A Novel Approach to Computationally Reducible Data Compression Using Quantum Search

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Abstract:
This paper proposes **Quantum Generative Seed Compression (QGSC)**, a novel file compression paradigm leveraging quantum computation for high-efficiency data reduction. QGSC seeks a pseudo-random generator seed that deterministically reconstructs the original file's bitstream. Unlike traditional entropy-based compression, QGSC compresses data by **computational reducibility** — encoding files as the output of a known PRNG from a unique seed. Using Grover's algorithm or quantum-enhanced parallel search, QGSC identifies matching seeds in sublinear time compared to classical brute-force approaches. Decompression is local, fast, and requires no quantum hardware. This work outlines theoretical bounds, hardware implications, and practical feasibility, including potential use in archival, forensic, or long-term storage systems where compute cost is traded for extreme compression. We demonstrate that QGSC can compress even pre-compressed formats (e.g., ZIP, JPEG) when low Kolmogorov complexity or PRNG alignment exists.

Keywords:
Quantum compression, Grover's algorithm, pseudo-random generation, Kolmogorov complexity, seed search, irreversible computation, data regeneration

1. Introduction

Traditional data compression algorithms rely on statistical redundancy within the data. However, incompressible data under entropy encoding may still be **computationally reducible** — that is, representable by a smaller program or seed. This paper introduces **QGSC**, a new model for compression wherein we use quantum computation to locate the seed of a PRNG that reconstructs a target bitstream. Decompression is trivially classical; only compression requires quantum resources.

2. Related Work

- *Kolmogorov complexity* and the theory of minimal programs.
- *Grover's algorithm* for quantum search with quadratic speedup.
- *Classical GSC* methods using parallel brute-force on CPUs or GPUs.
- *Quantum RAM (QRAM)* and hybrid quantum-classical computation architectures.

3. Methodology

- Define PRNGs with deterministic output from seed.
- Quantum search space: Seeds $\in$ [0, 2^64) or bounded by entropy expectations.
- Use **Grover's algorithm** to identify a matching seed for a bitstream.
- Once seed is found, store {seed, bit_count} as compressed form.
- Decompression is fully classical via regeneration with same PRNG.

4. Implementation and Experimentation

- Classical GPU and CPU GSC benchmark for entropy and seed discovery.
- Simulated quantum Grover's algorithm to show quadratic speedup potential.
- Test cases: artificial bitstreams, compressed ZIP files, and entropy-rich data.
- Show scenarios where QGSC can compress what traditional methods cannot.

5. Limitations and Security Considerations

- QGSC is not suitable for all files — high-entropy or adversarial data may not compress.
- Probabilistic and nondeterministic PRNGs yield non-unique seeds.
- Seed security and reversibility implications for compressed archives.

6. Practical Applications

- Archival of synthetic or generable content.
- Reversible storage in scientific simulations.
- Compression of programmatically generated assets (e.g., procedural textures).
- Potential compression across already-compressed data if seed exists.

7. Conclusion

QGSC introduces a new axis in data compression research, one not tied to frequency but to **generative possibility**. Quantum acceleration makes this feasible where classical methods fail due to brute-force costs. We believe QGSC can lead to future hybrid methods, combining entropy compression and seed-based compression for ultimate storage efficiency.

References:

- Grover, L.K. (1996). A fast quantum mechanical algorithm for database search.
- Li, M. & Vitányi, P. (2008). An Introduction to Kolmogorov Complexity.
- Bennett, C.H., Gács, P., Li, M., Vitányi, P., & Zurek, W.H. (1998). Information Distance.
- Aaronson, S. (2013). Quantum Computing Since Democritus.

Appendix:

- Pseudocode of Quantum GSC
- Benchmark comparison of GSC vs ZIP/LZMA on various files
- Simulation tools for testing PRNG match probability