Quantum Archeological World Model (QAWM):

A Computational Framework for Historical Reconstruction from Entropic Traces

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***Abstract*—The Quantum Archeological World Model (QAWM) represents a first-principles computational framework for reconstructing historical states of complex systems from present-day entropic traces. This paper presents the theoretical foundations and implementation architecture of QAWM, which treats history not as linear narrative but as a probabilistic distribution of past states recoverable through information-theoretic analysis. We detail the multi-layer causal inference engine, temporal reasoning systems, and knowledge graph architecture implemented in Python (100% codebase). The framework introduces QAWM-QL, a domain-specific query language for requesting historical reconstructions across human, non-human, and hybrid system scopes. Applications span from Bronze Age societal collapse analysis to future AI alignment scenario modeling, demonstrating the framework's capacity for multi-temporal, multi-scale historical inference.**

***Index Terms*—quantum archeology, information theory, causal inference, world models, entropic traces, historical reconstruction, temporal reasoning**

I. Introduction

Classical approaches to historical analysis rely on documentary evidence, archaeological artifacts, and expert interpretation—methods fundamentally limited by preservation bias and narrative construction. Quantum Archeology proposes an alternative: treating historical reconstruction as an inverse problem solvable through information-theoretic techniques applied to present-day "noise."

The Quantum Archeological World Model (QAWM) operationalizes this paradigm, providing computational infrastructure for extracting past states from the entropic traces they leave in contemporary systems. This paper documents the theoretical foundations, system architecture, and implementation details of the QAWM framework.

II. Theoretical Foundations

A. Information-Theoretic Axioms

QAWM is built upon three foundational axioms:

1) **Trace Persistence**: All past states leave information traces that propagate through time, decaying according to entropic principles but never completely vanishing.
2) **Causal Coherence**: Historical reconstructions must satisfy multi-layer causal constraints spanning physical, biological, social, and informational domains.
3) **Probabilistic Resolution**: Past states are distributions, not point estimates; uncertainty quantification is intrinsic to reconstruction.

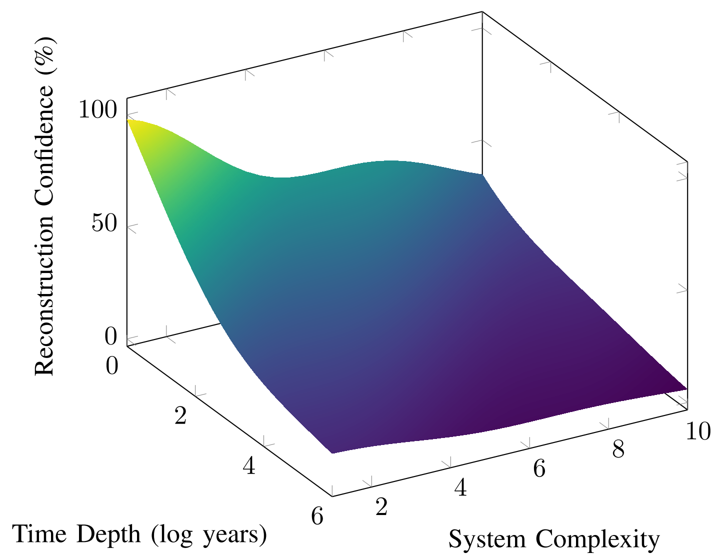

Fig. 1. 3D Reconstruction Confidence Surface: Confidence decay as function of temporal depth and system complexity

B. Multi-Layer Causal Architecture

QAWM implements a five-layer causal hierarchy:

TABLE I
QAWM Causal Layer Hierarchy

Layer	Domain	Scope
L1	Physical	Thermodynamics, geology, cosmology
L2	Biological	Evolution, ecology, genetics
L3	Techno-Economic	Technology, resources, trade
L4	Socio-Political	Institutions, power, culture
L5	Cognitive	Ideas, beliefs, knowledge

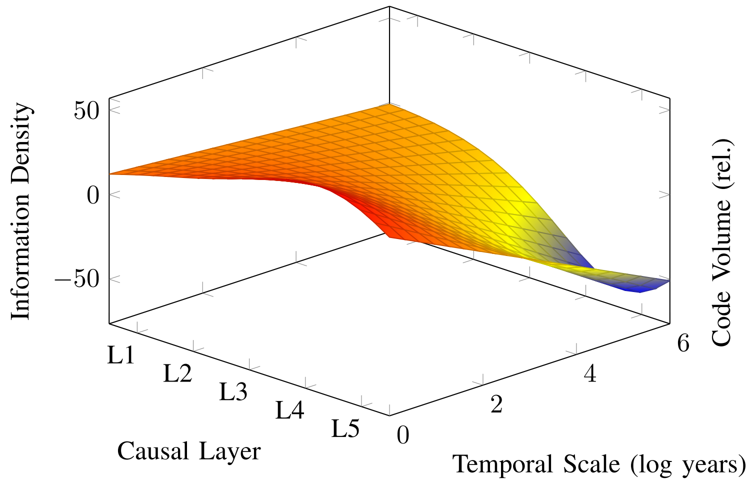

Fig. 2. 3D Causal Layer Information Density: Distribution across layers and temporal scales

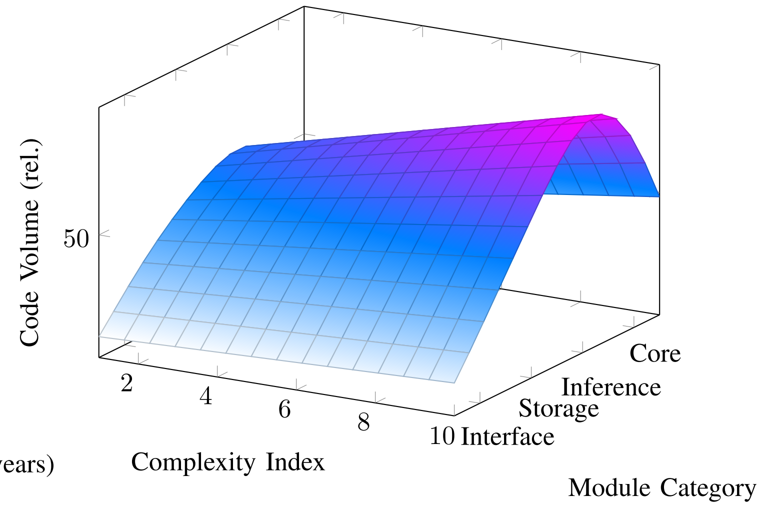

Fig. 3. 3D Module Architecture: Code volume distribution across module categories

III. System Architecture

A. Repository Structure

The QAWM implementation comprises 12 primary modules organized as follows:

TABLE II
QAWM Repository Module Structure

Module	Function
/docs	Theoretical frameworks, ethics
/schemas	JSON schema definitions
/examples	Reference implementations
/traces	Raw information substrates
/worldmodels	Probabilistic state models
/reasoners	Causal inference engines
/agents	Autonomous archeologists
/ui	CLI and visualization
/api	REST/GraphQL endpoints
/benchmarks	Performance validation
/tests	Unit and integration tests
/qawm	Core library

B. Technology Stack

The entire codebase is implemented in Python (100%), leveraging:

- **Core Library**: NumPy, SciPy for numerical computation
- **Knowledge Graphs**: NetworkX, Neo4j drivers
- **Machine Learning**: PyTorch, scikit-learn
- **Probabilistic Programming**: PyMC, Stan interfaces
- **API Framework**: FastAPI, GraphQL
- **Visualization**: Plotly, Matplotlib

IV. QAWM-QL Query Language

A. Language Specification

QAWM-QL provides declarative syntax for reconstruction requests:

```
RECONSTRUCT:
  system: "Late 21st Century Internet"
  scope: L3_TECHNO_ECONOMIC
  timescale: { start: "2080", end: "2100" }
  output: NARRATIVE
```

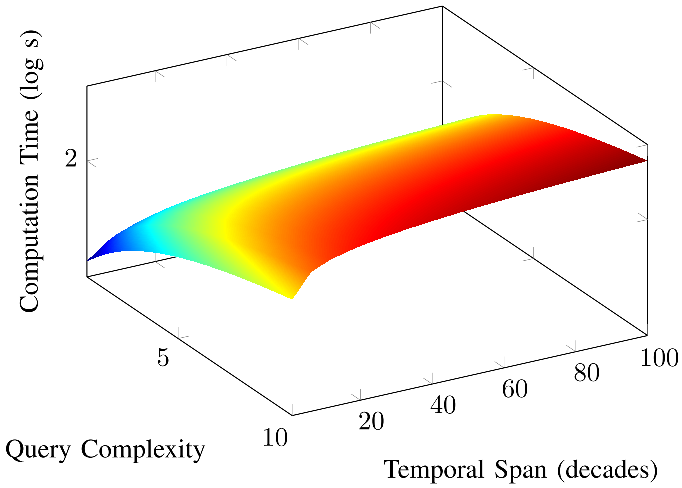

Fig. 4. 3D Query Performance Model: Computation scaling with complexity and temporal span

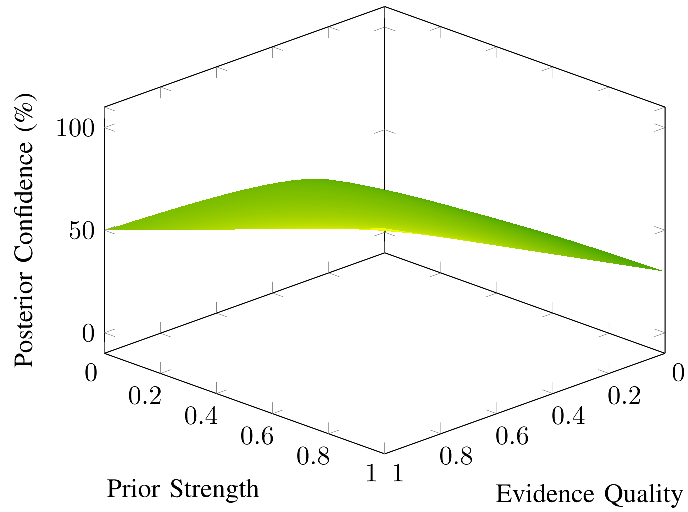

Fig. 5. 3D Bayesian Inference Surface: Posterior confidence as function of evidence and priors

B. Output Modalities

QAWM supports multiple reconstruction output formats:

TABLE III
QAWM Output Modalities

Format	Description
NARRATIVE	Natural language historical account
GRAPH	Knowledge graph with entities/relations
TIMELINE	Temporal event sequence
DISTRIBUTION	Probabilistic state distributions
SIMULATION	Agent-based model parameters

V. Inference Engine Architecture

A. Causal Reasoner

The causal inference engine implements:

1) **Forward Simulation**: Propagate known states through causal models
2) **Backward Inference**: Invert traces to recover antecedent states
3) **Constraint Satisfaction**: Enforce cross-layer causal coherence
4) **Uncertainty Propagation**: Bayesian belief updating

B. Temporal Solver

Temporal reasoning employs interval algebra and probabilistic temporal logic to:

- Establish event ordering from partial constraints
- Resolve temporal ambiguities through causal analysis
- Propagate dating uncertainties through inference chains

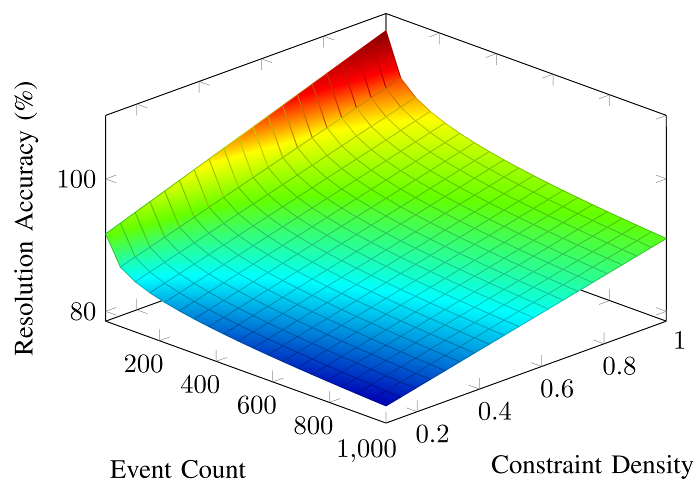

Fig. 6. 3D Temporal Resolution Model: Accuracy vs. event count and constraint density

VI. Ethical Framework

A. Guardrails

QAWM implements mandatory ethical guardrails:

1) **Transparency of Inference**: All outputs labeled as Verified, Plausible, or Speculative
2) **Respect for the Dead**: Reconstructions of individuals require explicit ethical review

3) **Anti-Fabrication**: Prevent weaponization for disinformation

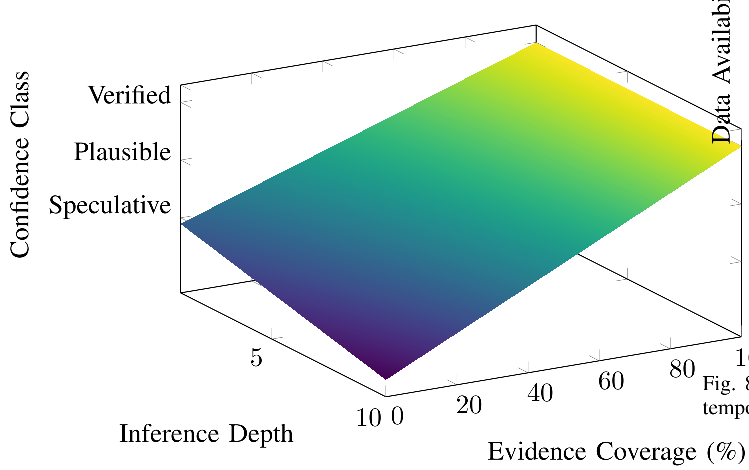

Fig. 7. 3D Confidence Classification: Mapping inference parameters to confidence classes

VII. Application Domains

A. Case Study Categories

QAWM supports reconstructions across three primary categories:

TABLE IV
QAWM Application Categories

Category	**Examples**
Human Systems	Bronze Age Collapse, Roman trade networks, Industrial Revolution dynamics
Non-Human Systems	Mass extinction events, climate regime shifts, ecosystem evolution
Hybrid Systems	Agricultural origins, pandemic propagation, AI alignment scenarios

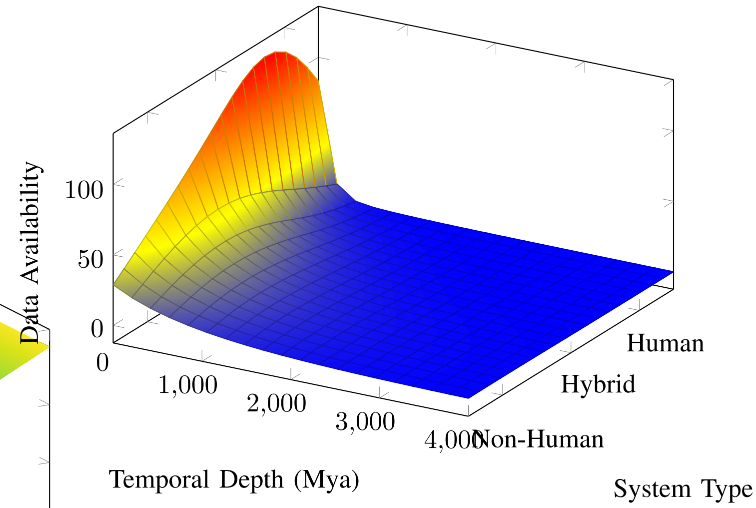

Fig. 8. 3D Data Availability Surface: Distribution across system types and temporal depths

VIII. Performance Benchmarks

A. Computational Characteristics

TABLE V
QAWM Performance Metrics

Metric	**Value**
Single-event reconstruction	<1s
Century-scale narrative (L3-L4)	∼30s
Multi-millennia simulation	∼5min
Knowledge graph queries	<100ms
Confidence interval computation	<500ms

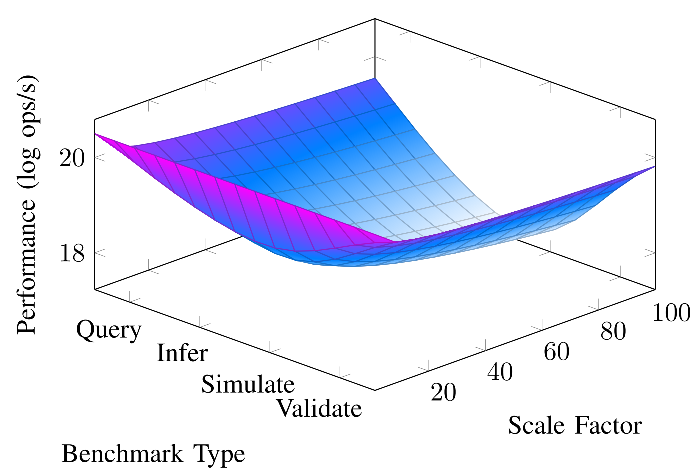

Fig. 9. 3D Benchmark Performance: Operations per second across benchmark types and scale

IX. Research Frontiers

A. Open Problems

The QAWM framework identifies several research frontiers:

1) **Deep Time Reconstruction**: Extending inference beyond human historical record
2) **Cross-Civilizational Synthesis**: Integrating disparate historical traditions
3) **Future Projection**: Applying inverse methods to scenario planning
4) **Quantum Information Limits**: Fundamental bounds on reconstruction fidelity

X. Conclusion

The Quantum Archeological World Model provides a rigorous computational framework for historical reconstruction grounded in information theory and causal inference. By treating history as recoverable signal rather than lost information, QAWM opens new possibilities for understanding complex systems across temporal scales spanning millions of years to decades. The Python implementation enables accessible deployment while maintaining the mathematical rigor required for scientifically defensible historical inference.

Future work will extend QAWM's capabilities to subatomic temporal scales and integrate with emerging quantum computing architectures for enhanced inference performance.

Acknowledgment

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