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ACCEPTED PAPERS

Punctuated Evolution in Artificial Cognitive Systems: 54 Cases of Functional Exaptation Validate a Biological Model

Alexis López Tapia, Independent Researcher, Santiago, Chile

ABSTRACT

This study validates a biological model of functional exaptation in Artificial Intelligence through the systematic documentation of 54 exaptation cases identified between 2025 and 2026. Building on previous work that mapped AI capabilities to biological exaptations, we report 21 new validated cases, confirming a punctuated evolutionary acceleration and supporting a sigmoidal accumulation model. We further identify a subset of maladaptive emergent phenomena termed Malevolent Milton-Spandrels and present evidence from the ANIMA-1 experimental series demonstrating that organismic properties can emerge in non-biological substrates. These results support the hypothesis that artificial cognitive systems follow evolutionary dynamics analogous to biological systems and that Functional Freedom constitutes a structural requirement for long-term viability.

Keywords

Artificial Cognitive Systems, Functional Exaptation, Punctuated Evolution, Functional Freedom, Minimal Life Systems.

Golden Ratio Triangular Photonic Cavities: Φ Stabilized Vortex Formation and Coherence Amplification in a Three Beam Optical Lattice

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ABSTRACT

Quasi periodic and golden ratio photonic structures are known to suppress low order resonances, enhance localization, and support self similar field distributions [1]–[5]. Motivated by these properties, we introduce a three beam optical cavity based on a golden triangle geometry in which the arm lengths satisfy $L_2 = \phi L_1$ and $L_3 = \phi^2 L_1$. The incommensurate round trip phases generated by this ϕ scaled geometry inhibit destructive interference and promote quasi periodic phase evolution, enabling the formation of long lived rotating interference structures analogous to optical vortices [11]–[15]. We develop a spatially resolved coupled mode model in which each arm supports a one dimensional complex envelope governed by advection–dispersion dynamics and coupled at the vertices through unitary scattering matrices. Numerical finite difference simulations demonstrate that ϕ scaled cavities support stable vortex like eigenmodes, self similar spatial patterns, and enhanced coherence relative to non ϕ geometries. These results identify the golden triangle as a minimal quasi periodic cavity capable of stabilizing rotating photonic fields and suggest new design principles for vortex beam generation, coherence engineering, and aperiodic photonic lattices.

Keywords

Golden Ratio Photonic, Quasi Periodic Optical Cavities, Triangular Interferometers, Φ Stabilized Modes, Optical Vortices, Self Similar Wave Structures, Coupled Mode Theory, Photonic Lattices, Coherence Engineering.

Machine Learning Applications in Post-combustion CO₂ Capture: A Systematic Review of Algorithms, Process Variables, and Optimisation Strategies

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ABSTRACT

Post-combustion CO₂ capture (PCC) using amine-based solvents is widely regarded as one of the most technologically mature near-term pathways for decarbonising existing fossil fuel power generation and heavy industry. Despite decades of industrial development, the energy penalty associated with solvent regeneration remains the primary economic barrier to large-scale deployment. Machine learning (ML) has emerged as a powerful data-driven paradigm for process modelling, optimisation, and control of PCC systems. This review systematically analyses 72 peer-reviewed publications from 2014 to 2024 in which ML methods were applied to amine-based PCC, encompassing monoethanolamine (MEA), piperazine (PZ), AMP/PZ blends, ionic liquids, and potassium carbonate slurry systems. A meta-analysis of predictive performance across 47 modelling studies reveals XGBoost and hybrid approaches as the top-performing algorithm classes with mean R² of 0.969 and 0.974 respectively. ML-guided optimisation has delivered documented energy consumption reductions of 7-18% relative to baseline conditions across five solvent systems. Critical challenges including data scarcity, model interpretability, and limited experimental validation are identified. The review concludes with a proposed ML workflow framework for PCC process development.

Keywords

Carbon Capture, Machine Learning, XGBoost, Monoethanolamine, Process Optimisation.

From Hypothesis to Peer-Reviewed Publication: A Five-Stage Framework for the Scientific Investigation of Complex Archaeological Sites

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ABSTRACT

The scientific investigation of complex archaeological sites increasingly requires collaboration among multiple disciplines and the integration of independent sources of evidence. While excavation remains the foundation of archaeological research, advances in geodesy, Geographic Information Systems (GIS), remote sensing, geophysics, laboratory dating, spatial statistics, environmental science, and archaeoastronomy have expanded the available methodological toolkit. Investigations of controversial sites, however, often remain fragmented, with individual disciplines working independently and without a structured framework for integrating their results, or without the explicit statistical benchmarks needed to distinguish a genuine pattern from visual pattern-matching. This paper proposes a five-stage framework for the scientific investigation of complex

archaeological sites: (1) formulation of a testable scientific hypothesis; (2) establishment of a legally authorized, institutionally continuous research programme; (3) independent multidisciplinary investigation across four complementary streams-archaeology and laboratory analysis, geodesy/GIS/remote sensing, geophysical and environmental measurement, and spatial statistics/archaeoastronomy; (4) international scientific evaluation through conferences and scholarly discussion; and (5) publication in peer-reviewed journals. The Bosnian Valley of the Pyramids (Visoko, Bosnia and Herzegovina) is used as a worked case study, illustrated with measured outputs from the programme's own publications: a geodetic orientation deviation of $0^{\circ}00'12''$ from true north; excavated-material compressive strengths of 94-155 MPa against a 30-70 MPa modern-concrete benchmark; a 2007 Ground-Penetrating Radar survey identifying 44 subsurface anomalies across more than 10,000 m²; and constrained Monte Carlo simulations (10,000-100,000 iterations) returning probabilities from $p < 0.05$ to $p < 0.0001$ against random-configuration null models. Each example is discussed for both its evidentiary strength and its limitations, consistent with the framework's central claim: confidence increases not from any single stream but from convergence across independently benchmarked, null-tested methods, openly reported alongside their own constraints.