

# **Proposal: Anarchy, Nonlinearity, and Emergence in International Relations - A Quantum Spiking Neural Network Framework Approach -**

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## **Abstract**

This research proposes a novel approach to modeling international relations by leveraging Quantum Spiking Neural Networks (QSNNs), integrating quantum computing principles with event-based neural dynamics. While existing systems theory methods have provided valuable insights, they face critical limitations in representing the rich qualitative diversity of international events. Traditional approaches treat events as scalar occurrences or categorical variables, unable to capture subtle gradations in event meaning, intensity, and strategic ambiguity. The QSNN framework addresses this through quantum state representation on the Bloch sphere: each event is encoded as a quantum state vector with unit norm but distinct phase and amplitude components, enabling continuous high-dimensional representation of event qualities while maintaining geometric structure. This quantum encoding allows us to distinguish infinite varieties of events through their positions on the Bloch sphere, apply quantum theoretical physics methods (geometric phases, quantum field theory, entanglement measures) to analyze interstate relational structures, and naturally represent superposition-like phenomena in international politics. Combined with event-based computing architecture, QSNNs achieve computational efficiency for sparse event data while enabling application of advanced theoretical physics analysis tools. Our methodology employs international event databases with quantum encoding schemes, developing automated quantum circuit discovery for event representation and dynamical evolution. Expected contributions include a quantum-theoretic paradigm for IR modeling, quantum-enhanced equation discovery methods, insights into entanglement structures in alliance networks, and policy simulation incorporating quantum interference effects.

Under a relation-centered definition of research objects, International Relations (IR) research focuses on relational structures that transcend national boundaries and the phenomena that

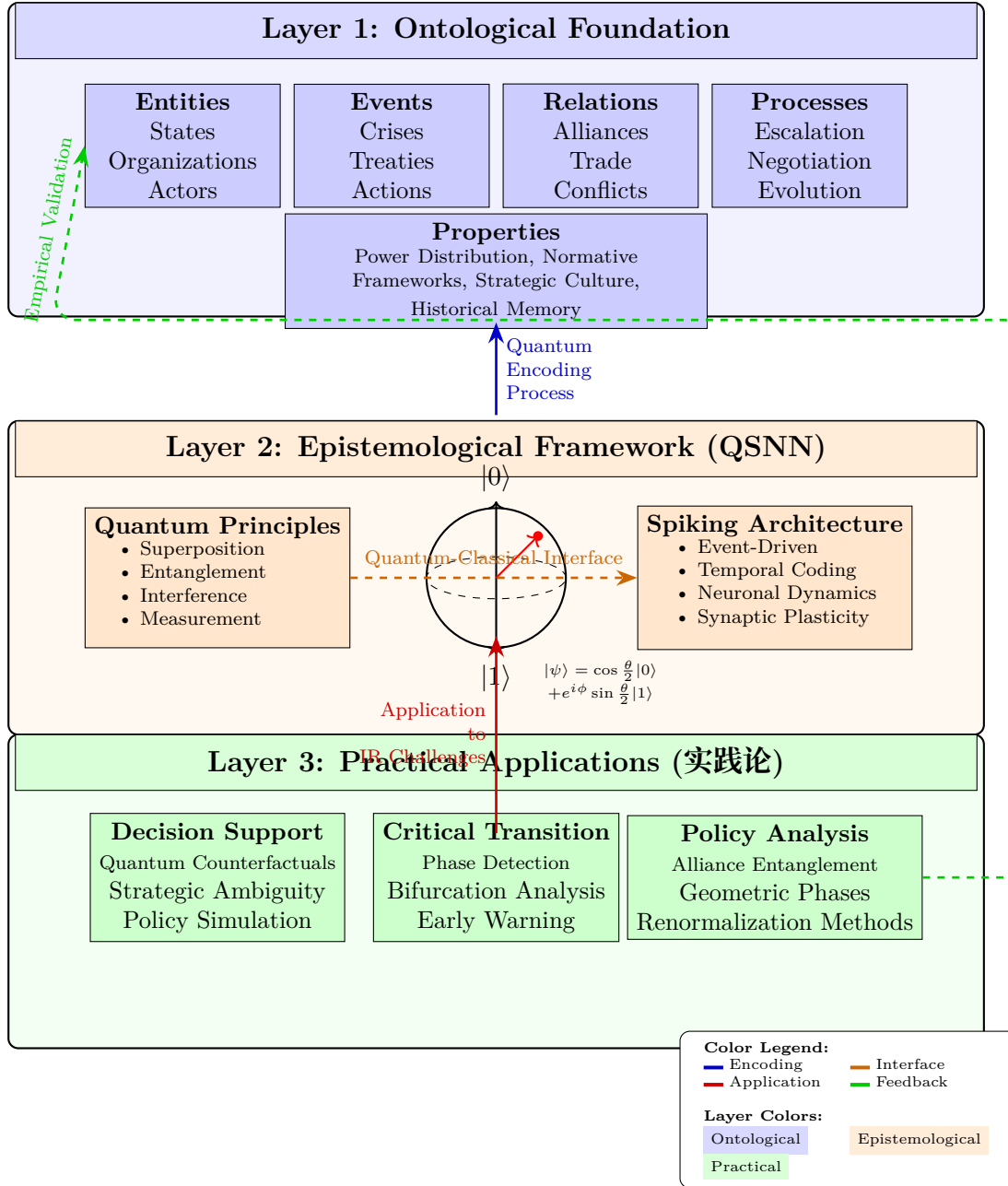


Figure 1: **Conceptual Framework of QSNN for International Relations:** A three-layer architecture showing (1) the ontological foundation of IR phenomena, (2) our proposed QSNN framework with quantum event encoding on the Bloch sphere, and (3) practical applications in decision-making and policy analysis. Arrows indicate information flow and theoretical relationships between layers.

emerge from these structures. Due to the highly abstract nature of concepts such as relations and objects, social science research typically employs operationalization methods to transform IR concepts into operational and analyzable symbolic structures. This process enables the application of techniques from natural sciences and engineering to IR research.

Systems theory approaches constitute an important methodological toolkit in IR research.

For example: (1) Agent-based modeling (ABM) treats states and international organizations as autonomous units within a system, studying macro-level international phenomena through simulating their interactions Cederman 2003; Axelrod 1997; (2) Network analysis methods model interstate relations such as trade, alliances, and conflicts as complex networks, revealing structural characteristics of the international system Hafner-Burton, Kahler, and Montgomery 2009; Maoz 2010; (3) Dynamical systems theory is employed to analyze stability, critical points, and phase transitions in international relations Jervis 1997; Richardson 1960.

According to Li’s introduction of international policies 李少军 2019, the fact entites in international relation involve: (1) states, (2) properties, (3) relations, (4) processes, and (5) events. However, existing systems theory approaches face fundamental limitations in both temporal modeling of (1) to (4) and event representation: (1) **Temporal representation mismatch:** International relations evolve through discrete events (diplomatic crises, treaty signings, military actions) that trigger continuous cascading effects. Traditional continuous-time dynamical systems assume smooth state evolution and cannot naturally represent discrete event occurrences, while discrete agent-based models impose artificial time-step discretization, missing the asynchronous nature of international politics. (2) **Impoverished event representation:** Existing methods represent events as scalar occurrences (binary event/no-event), categorical variables (event type labels), or low-dimensional feature vectors. This fails to capture the rich qualitative diversity of international events—their intensity, context, normative valence, strategic ambiguity, and multi-dimensional meanings. A ”diplomatic protest” can range from perfunctory ritual to severe warning, but current representations cannot encode these subtle gradations in a mathematically principled way. (3) **Inability to model superposition and interference:** International political phenomena often exhibit superposition-like characteristics—actors maintaining simultaneously cooperative and competitive stances, events carrying multiple simultaneous interpretations, policies existing in ambiguous states until ”measured” through implementation. Classical representations lack mathematical structures to formalize such phenomena. (4) **Limited analytical toolkit:** Traditional dynamical systems restrict analysis to phase space geometry and bifurcation theory. The rich mathematical structures from quantum field theory, geometric topology, and gauge theory remain inaccessible because classical event representations lack the necessary mathematical properties (Hilbert space structure, unitarity, gauge invariance).

This research proposal attempts to model and analyze international relations using the

Quantum Spiking Neural Networks (QSNN) framework **kouda2005qubit; russell2017quantum**, which integrates quantum computing principles with event-based neural computation. The quantum extension provides transformative capabilities beyond classical SNNs through quantum state representation on the Bloch sphere.

In the QSNN framework, each international event is encoded as a quantum state  $|\psi\rangle$  on the Bloch sphere, represented as  $|\psi\rangle = \cos(\theta/2)|0\rangle + e^{i\phi}\sin(\theta/2)|1\rangle$ , where  $\theta \in [0, \pi]$  and  $\phi \in [0, 2\pi)$  specify the state's position on the sphere. Crucially, all event vectors have unit norm  $\langle\psi|\psi\rangle = 1$ , but differ in their phase  $\phi$  and amplitude distribution (controlled by  $\theta$ ). This geometric structure provides several revolutionary advantages: (1) **Infinite event differentiation**: The continuous phase space  $[0, 2\pi)$  allows encoding infinitely many distinct event types and intensities. Unlike categorical encoding (finite discrete types) or classical vectors (requiring arbitrary dimension choices), the Bloch sphere provides a natural, geometrically principled continuous event space. Two events with the same "type" but different intensities or contexts are represented as nearby points on the sphere, with their angular separation quantifying similarity. (2) **Geometric phase and Berry curvature**: As events evolve through sequences (e.g., escalation cycles), their quantum state traces paths on the Bloch sphere. The geometric phase accumulated along closed paths—a purely topological quantity independent of parametrization—can represent path-dependent effects in international relations, such as how the "same" sequence of events produces different outcomes depending on the trajectory taken. This connects IR phenomena to gauge theory and differential geometry **berry1984quantal**. (3) **Quantum interference in event superposition**: Multiple potential events or policy options can be represented as quantum superpositions  $|\psi\rangle = \alpha|\psi_1\rangle + \beta|\psi_2\rangle$ . When events "collapse" (are realized), interference terms  $\alpha^*\beta + \alpha\beta^*$  capture how the combination of potential actions produces effects beyond simple linear superposition—formalizing strategic ambiguity and commitment problems in game-theoretic situations. (4) **Entanglement for relational structures**: Multi-actor states can be represented as entangled quantum states  $|\Psi\rangle_{AB} \neq |\psi\rangle_A \otimes |\phi\rangle_B$ , where actors  $A$  and  $B$  cannot be described independently. This provides a mathematical formalization of deep interdependence in alliances or security dilemmas, where measurement (observation of one actor's action) instantaneously affects the state description of others. Entanglement entropy quantifies the degree of interdependence **nielsen2010quantum**. (5) **Quantum field-theoretic analysis**: The QSNN framework enables application of quantum field theory (QFT) methods to IR. Relations can be modeled as quantum fields, with events corresponding to field excitations. Group

field theory **orit2009group** provides tools for analyzing how relational structures emerge from fundamental interaction events. Renormalization group methods can study how IR patterns appear different at different observational scales (bilateral, regional, global). (6) **Topological and geometric methods:** Quantum representations enable topological data analysis on the space of international events. Persistent homology can identify robust structural features in event sequences, while quantum geometric tensor components reveal intrinsic curvature of the event manifold, indicating regions where small parameter changes produce disproportionate effects.

The event-based computing architecture inherent to spiking neural networks combines naturally with quantum representation. Each quantum spike carries a quantum state  $|\psi\rangle$  rather than a classical binary pulse. Neuronal membrane potentials evolve as quantum states, with spike emission occurring when quantum measurement collapses the state. Synaptic dynamics implement quantum channels that evolve relationship states through unitary operations or quantum measurements, with synaptic plasticity rules operating on the quantum state space. This event-driven quantum computation achieves efficiency for sparse IR event data while maintaining the expressiveness of quantum state spaces.

Compared to classical SNN approaches, QSNN provides: (1) **Structured infinite-dimensional event space:** The Bloch sphere geometry provides principled continuous event encoding without arbitrary dimensionality choices; (2) **Access to quantum theoretical physics:** Geometric phases, gauge theories, entanglement measures, quantum field methods become applicable; (3) **Natural representation of uncertainty and ambiguity:** Quantum superposition formalizes irreducible strategic uncertainty before "measurement" (action realization); (4) **Topological robustness:** Topological quantum numbers (winding numbers, Chern numbers) provide discrete invariants characterizing qualitative IR phenomena, robust against continuous perturbations.

As concrete implementation, policies and behavioral patterns are encoded as quantum unitary operators acting on neuronal quantum states, governing how actors' internal states respond to incoming quantum events. Relations between entities are encoded as quantum channel dynamics governing how entangled relationship states evolve based on quantum interaction history. International events are converted into quantum spike trains, with each spike carrying a Bloch sphere state vector encoding event characteristics. The quantum event-driven architecture ensures computation occurs only when quantum events happen, maintaining efficiency.

This research will utilize the following data sources: (1) **Event data**: International event databases such as GDELT Leetaru and Schrodtt 2013 and ICEWS Boschee et al. 2015, extracting event types, timestamps, and involved actors. Events are mapped to the Bloch sphere through learned encodings that preserve semantic similarity (similar events map to nearby quantum states). (2) **Relational data**: Trade flows (UN Comtrade), alliance relations (COW) Singer and Small 1972, diplomatic visit records, used to initialize quantum entanglement structures and validate quantum channel dynamics. (3) **Behavioral data**: National policy texts and voting records, extracting features through NLP methods and mapping them to quantum operator parameters.

Addressing the core question of "how to determine appropriate quantum neuronal and synaptic evolution operators," this research will develop: (1) **Quantum circuit architecture search**: Employing variational quantum algorithms [cerezo2021variational](#) and quantum neural architecture search to discover optimal quantum circuit structures for neuronal evolution and synaptic updates, searching over parameterized quantum gates (rotation gates, entangling gates) to match historical data. (2) **Quantum-enhanced symbolic regression**: Extending classical symbolic regression [Schmidt and Lipson 2009](#); [Cranmer et al. 2020](#) to discover quantum Hamiltonian structures and Lindblad operators governing open quantum system dynamics, leveraging the structured neuron-synapse decomposition. (3) **Geometric optimization**: Optimizing directly on quantum state manifolds using quantum natural gradient methods [stokes2020quantum](#), exploiting the Riemannian geometry of quantum state space. (4) **Validation through quantum tomography**: Reconstructing quantum states and processes through quantum state tomography and process tomography to verify learned quantum dynamics against empirical data, evaluating predictive power through quantum counterfactual simulations.

The main objectives of this research include: (1) Designing and developing a scalable quantum-classical hybrid infrastructure supporting flexible customization of quantum neuronal and synaptic dynamics, encompassing software simulation (using quantum computing frameworks like Qiskit, Cirq) and potential neuromorphic quantum hardware deployment; (2) For specific IR cases (great power competition dynamics, regional alliance evolution, nuclear deterrence stability), automatically exploring and validating appropriate quantum event encodings and evolution operators through data-driven methods; (3) Applying quantum dynamical systems theory (quantum bifurcation analysis, entanglement dynamics), quantum field the-

ory (renormalization group analysis, symmetry breaking), and quantum topology (topological phases, Chern numbers) **wen2004quantum** to analyze emergent mechanisms revealed by the model.

The expected contributions of this research include: (1) **Methodological innovation:** Establishing quantum event-based computing as a paradigm for IR systems modeling, providing a quantum-theoretic temporal-relational framework that resolves representation limitations in classical approaches while enabling application of advanced theoretical physics methods. (2) **Technical outputs:** Developing open-source quantum-classical hybrid SNN infrastructure with quantum circuit libraries for IR applications, quantum event encoding schemes, and data processing pipelines, lowering barriers for quantum social science modeling. (3) **Theoretical insights:** Through concrete case analyses, revealing topological phase transitions, quantum entanglement structures in alliance networks, geometric phase effects in escalation dynamics, and quantum interference patterns in policy superposition—phenomena invisible to classical analysis but potentially explanatory of puzzles in IR theory. (4) **Applied value:** Providing quantum-enhanced policy simulation tools that incorporate strategic ambiguity through superposition, analyze entanglement-based interdependence structures, and support counterfactual reasoning with quantum interference effects, offering new capabilities for strategic analysis in an uncertain international environment.

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