Extended-Dimensional Information Dynamics (EIDU): A Structural Framework for Dimensional Projection, Temporal Irreversibility and Unified Entropy

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Abstract

We propose **Extended-Dimensional Information Dynamics (EIDU)**, a unifying framework in which the physical universe arises as a sequence of irreversible projections of a high-dimensional information structure (HIS). Observable physics in dimension n is described by a projection $P_n : \mathcal{H} \to D_n$, where D_n is the effective state space. Temporal evolution corresponds to the irreversible sequence of accessible 3D frames $F_k = P_3(U^k(h_0))$, generated by a high-dimensional update operator U acting on $\mathcal{H}$.

A single high-dimensional *Proto-Entropy* $\Phi : \mathcal{H} \to \mathbb{R}_{\geq 0}$ projects into thermodynamic, informational and geometric entropies. Irreversibility arises from the non-invertibility of P_n, quantified by an **Information Loss Functional** $\mathcal{I}_n : \mathcal{H} \to \mathbb{R}_{\geq 0}$. This Mini-Paper establishes the structural core of EIDU.

1 Introduction

The search for a structurally unified description of physical law has historically proceeded along two largely independent paths: the geometrical formulation of spacetime dynamics, represented by general relativity, and the quantum-theoretic account of information, uncertainty and measurement. Despite major progress in both domains, a comprehensive theoretical framework capable of integrating the dimensional structure of spacetime, the informational structure of quantum theory and the emergence of thermodynamic irreversibility remains elusive.

A recurring theme in modern approaches is the hypothesis that observable low-dimensional physics may arise as a restricted view of a higher-dimensional or information-theoretic substrate. Examples include holographic dualities, tensor network models, emergent spacetime scenarios, and informational reconstructions of quantum theory. However, these approaches typically presuppose either an embedding geometry or an underlying quantum field structure and thus do not directly address the ontological relation between dimensional hierarchy, entropy and temporal ordering.

In this Mini-Paper we introduce *Extended-Dimensional Information Dynamics* (EIDU), a formally minimal framework in which the universe is represented as a high-dimensional information structure $\mathcal{H}$ together with a family of dimension-lowering projections $P_n : \mathcal{H} \to D_n$. Within EIDU, the observed temporal sequence of 3D states arises not from a fundamental geometric time dimension but from irreversible access to successive projections of an update operator $U : \mathcal{H} \to \mathcal{H}$. The structural non-invertibility of the projections yields an intrinsic arrow of time, independent of statistical assumptions.

A single high-dimensional *Proto-Entropy* functional Φ gives rise, under projection, to thermodynamic, informational and geometric entropy measures in three dimensions. The difference between Φ and its effective projections is captured by an *Information Loss Functional* $\mathcal{I}_n$, which quantifies the irrecoverable high-dimensional degrees of freedom suppressed by the projection P_n.

The purpose of this Mini-Paper is not to provide a complete dynamical theory but to establish the core structural elements, mathematical operators and irreversibility relations that define EIDU as a candidate framework for unifying dimensional hierarchy, entropy differentiation and the emergence of temporal ordering.

2 High-Dimensional Information Structure

Let $\mathcal{H}$ be the high-dimensional information structure (HIS), with elements $h \in \mathcal{H}$ representing full informational configurations. Let $\mathcal{I}$ be a set of primitive information units and $\mathcal{C} = \mathcal{I}^{\mathbb{N}}$ the space of information chains.

We define the **Proto-Entropy** functional:

$$\Phi : \mathcal{H} \to \mathbb{R}_{\geq 0}.$$

No geometric assumptions are imposed on $\mathcal{H}$.

3 Dimensional Stacking

Let D_n be the effective n-dimensional state space. We introduce a stacking operator:

$$\text{Stack}_n : \mathcal{S}(D_{n-1}) \to D_n,$$

where $\mathcal{S}(D_{n-1})$ is a suitable structured set. In particular,

$$D_4 \approx \text{Stack}_4(D_3),$$

interpreted as the "true-time" structure arising from stacked 3D states.

4 Projection and Information Loss

Observable physics is given by a projection:

$$P_n : \mathcal{H} \to D_n.$$

Since P_n is non-invertible, we introduce the **Information Loss Functional (ILF)**:

$$\mathcal{I}_n : \mathcal{H} \to \mathbb{R}_{\geq 0}.$$

We impose the structural properties:

- **Non-negativity**: $\mathcal{I}_n(h) \geq 0$.
- **Monotonicity under update**:
$$\mathcal{I}_n(U(h)) \geq \mathcal{I}_n(h).$$
- **Invertibility condition**:
$$\mathcal{I}_n(h) = 0 \quad \Leftrightarrow \quad P_n \text{ is invertible (not physically realized).}$$

We also define the decomposition:

$$\Phi(h) = \Phi_n(P_n(h)) + \mathcal{I}_n(h),$$

where Φ_n is the projected entropy observable in n dimensions.

5 Origin of Time: Frame Sequence

Let $U : \mathcal{H} \to \mathcal{H}$ be an update operator. The sequence of observable 3D states is:

$$F_k = P_3(U^k(h_0)).$$

The experienced temporal order is the index k. Non-invertibility of P_3 ensures:

$$F_{k+1} \neq F_k \quad \Rightarrow \quad \mathcal{I}_3(U^k(h_0)) > 0,$$

producing intrinsic temporal irreversibility.

6 Unified Entropy

Thermodynamic, informational, and geometric entropies in 3D are projections of Φ:

$$S_{\text{th}}(F_k) = E_{\text{th}}(\Phi, P_3, F_k),$$
$$S_{\text{info}}(F_k) = E_{\text{info}}(\Phi, P_3, F_k),$$
$$S_{\text{geom}}(F_k) = E_{\text{geom}}(\Phi, P_3, F_k).$$

7 Conclusion

EIDU provides a structural framework in which:

- Time arises from irreversible frame access.
- Entropy types are differentiated projections of a single Φ.
- Quantum randomness and classical irreversibility follow from projection non-invertibility.

Future work will develop mathematical models, toy universes, and physical predictions.

Framework Scope. We emphasize that EIDU, in its current form, is a *conceptual and structural mathematical framework*, not a complete physical theory with empirical predictions. Its current value lies in offering a formally minimal architecture within which foundational problems—including dimensional hierarchy, entropy differentiation and temporal irreversibility—may be reformulated in a unified manner. Empirical relevance will depend on future work that instantiates specific dynamical models within this framework, derives quantitative predictions, and establishes connections with existing physical theories. The present manuscript is intended only to lay the structural groundwork for such developments.

References

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