Emergent Spacetime from Probabilistic Planck-Scale Pixels Governed by a Deeper Rule Set: A Conceptual Proposal

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Abstract

We propose a conceptual framework in which spacetime is not fundamental, but emerges from discrete Planck-scale pixels whose states are described by wavefunctions. Each pixel has infinite possible states, probabilistically constrained by the local mass/energy density, and evolves according to a *deeper rule set*. Macroscopic spacetime geometry and classical curvature emerge statistically from the collective contributions of many pixels. At the Planck scale, spacetime is not smooth, while smoothness appears only at larger scales due to averaging over many probabilistic pixels. This work is intended as a **conceptual proposal** to inspire further theoretical exploration, rather than a fully developed predictive theory. We introduce a digital-display analogy as a conceptual tool to help visualize how pixels collectively produce emergent geometry.

Introduction

Current physical theories treat spacetime as a smooth, continuous manifold: general relativity models gravity as curvature, while quantum mechanics governs particles and fields. Near the Planck scale ($\sim 1.6\times10^{-35}$ m), quantum effects dominate, and classical geometry is expected to break down. Approaches such as loop quantum gravity, holographic principles, and emergent gravity suggest spacetime may have a discrete underlying structure. However, the fundamental mechanism connecting microscopic structure to macroscopic geometry remains unclear.

Here, we propose a framework in which spacetime emerges from probabilistic Planck-scale pixels whose behavior is controlled by a **deeper rule set**. This framework separates: 1. Fundamental units (pixels), 2. Rules governing their collective behavior, and 3. Emergent classical spacetime, providing a clear conceptual hierarchy for studying quantum spacetime.

Key Concepts

1. **Planck-Scale Pixel:** The smallest unit of spacetime. May have minimal geometric content, but spacetime is not smooth at this scale. Each pixel is described by a wavefunction representing an **infinite set of possible states**.

2. **Deeper Rule Set:** An abstract algorithm or logic gate that determines how a pixel behaves probabilistically based on local mass/energy density and interactions with

neighboring pixels. Without this rule set, pixels are inert and do not contribute to curvature.

3. **Probabilistic Behavior:** Pixels are not deterministic; they have intrinsic randomness constrained by the deeper rule set. This microscopic irregularity explains why spacetime is rough at the Planck scale.

4. **Emergent Spacetime:** Classical macroscopic spacetime and smooth curvature arise statistically from many pixels collectively contributing according to their wavefunctions and the deeper rules.

Conceptual Framework

Pixel Dynamics

Each pixel's wavefunction encodes the probabilities of its possible states. The deeper rule set acts as a probabilistic logic gate that biases these probabilities based on local mass/energy density and interactions with neighboring pixels. The pixel's state determines its contribution to the emergent curvature in its region.

Emergence of Macroscopic Geometry

Many pixels collectively "light up" according to the deeper rules and probabilistic dynamics. The sum over contributions produces macroscopic curvature, distance, and smooth geometry. At the Planck scale, curvature is discontinuous and irregular due to stochastic pixel states.

Digital Display Analogy (Conceptual Tool)

To aid intuition, we introduce an analogy:

Each Planck-scale pixel is like a pixel on a digital screen. The deeper rule set acts like an algorithm, similar to logic gates, controlling which pixels "light up" or contribute to the image, based on inputs such as local mass/energy density. The emergent spacetime geometry is analogous to the final image on the screen: no single pixel determines the whole, but the collective pattern produces a coherent macroscopic outcome.

Note: This analogy is a conceptual tool only. It is used to illustrate how probabilistic, constrained pixel behavior can generate emergent geometry.

Implications and Potential Applications

- Planck-scale roughness and quantum fluctuations of spacetime naturally arise from probabilistic pixel behavior.
- Emergent macroscopic geometry is deterministic only statistically, consistent with classical observations.
- Provides a conceptual framework for simulations of quantum spacetime networks.
- Suggests connections between quantum information principles and emergent gravity phenomena.

Conclusion

We propose that spacetime emerges from **Planck-scale pixels** whose infinite possible states are probabilistically constrained by local mass/energy density and governed by a **deeper rule set**. Pixels act like logic-gated quantum units: inert individually, they collectively generate emergent curvature.

This framework explains Planck-scale roughness, highlights a mechanism for emergent classical spacetime, and aims to inspire theoretical and computational explorations of quantum spacetime.

References

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