A Quantized Field Visualization of the SBSA Hypercube Wave Dynamics System

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Abstract

The SBSA (Size-Based Spatial Addressing) Hypercube Wave Dynamics System introduces a novel quantized and injective framework for modeling multidimensional waves in discrete space. This paper presents the mathematical formulation, injective address proof, and a 3D-angled interactive visualization using real-time field rendering. Applications in signal processing, quantum state modeling, and hyperdimensional encoding are proposed.

1 Introduction

Classical wave models assume continuous domains. The SBSA model redefines this by operating over a quantized four-dimensional grid: Size (s), Thickness (t), Width (w), and Version (v). Each state in this grid is uniquely addressable and supports a superposition of sinusoidal wave functions.

2 Mathematical Model

2.1 SBSA Wave Function

Let the wave function be defined as:

$$\Psi(s,t,w,v) = \sum_{i=1}^{N} A_i \cdot \sin(k_i x + \phi_i + \omega t) \tag{1}$$

Where:

- $s \in \{0,1,2,3\}$ denotes size class.
- $t = Q(t, \Delta_t)$ is quantized time, $\Delta_t = 5$.
- $w = Q(w, \Delta_w)$ is quantized width, $\Delta_w = 0.05$.
- $v \in [0, 10000]$ is version.

The quantization operator is:

$$Q(x, \Delta) = \Delta \cdot \text{round}\left(\frac{x}{\Delta}\right) \tag{2}$$

2.2 Addressing Function

Each state is mapped to a unique address:

$$\text{addr}(s,t,w,v) = s|T||W||V| + t|W||V| + w|V| + v \tag{3}$$

Where:

$$\begin{aligned} |T| &= 200001, \\ |W| &= 19999981, \\ |V| &= 10001 \end{aligned}$$

2.3 Injectivity Proof

Assume:

$$\text{addr}(s,t,w,v) = \text{addr}(s',t',w',v') \tag{4}$$

Expanding yields:

$$(s-s')|T||W||V| + (t-t')|W||V| + (w-w')|V| + (v-v') = 0$$

Given the domain constraints and scale of the coefficients, this equality only holds if:

$$s = s', \quad t = t', \quad w = w', \quad v = v'$$

Thus, the function is injective.

3 Visualization System

The SBSA system includes an HTML/JavaScript interface rendering the field as a tilted 3D projection. Each wave point uses the quantized address to define phase and amplitude, giving the impression of depth and perspective. Real-time controls allow users to adjust amplitude, frequency, and resolution.

4 Applications and Future Work

- **Quantum Visualization**: Encoding multi-qubit states in a 4D grid.
- **Data Compression**: Unique, injective memory addressing.
- **Signal Analysis**: Real-time field evolution with discrete harmonics.
- **Visual Computing**: Generative rendering of dynamic fields.

5 Conclusion

The SBSA model offers a powerful framework for discrete multidimensional wave modeling with proven injectivity, real-time visual feedback, and potential cross-disciplinary applications. The interactive tilted 3D field serves as both a computational tool and a conceptual demonstration of quantized field theory.

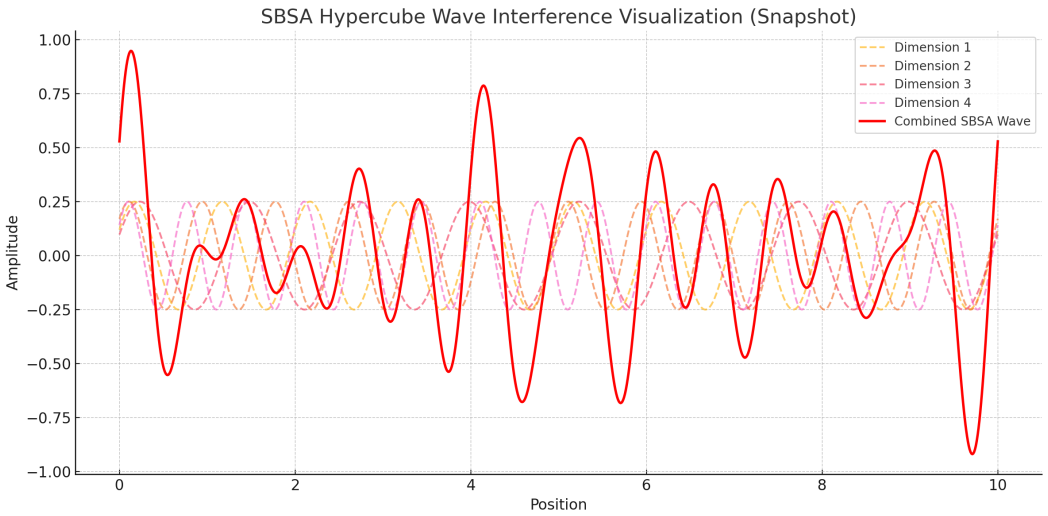

Figure 1: SBSA Wave Interference Visualization (4D interference projection)

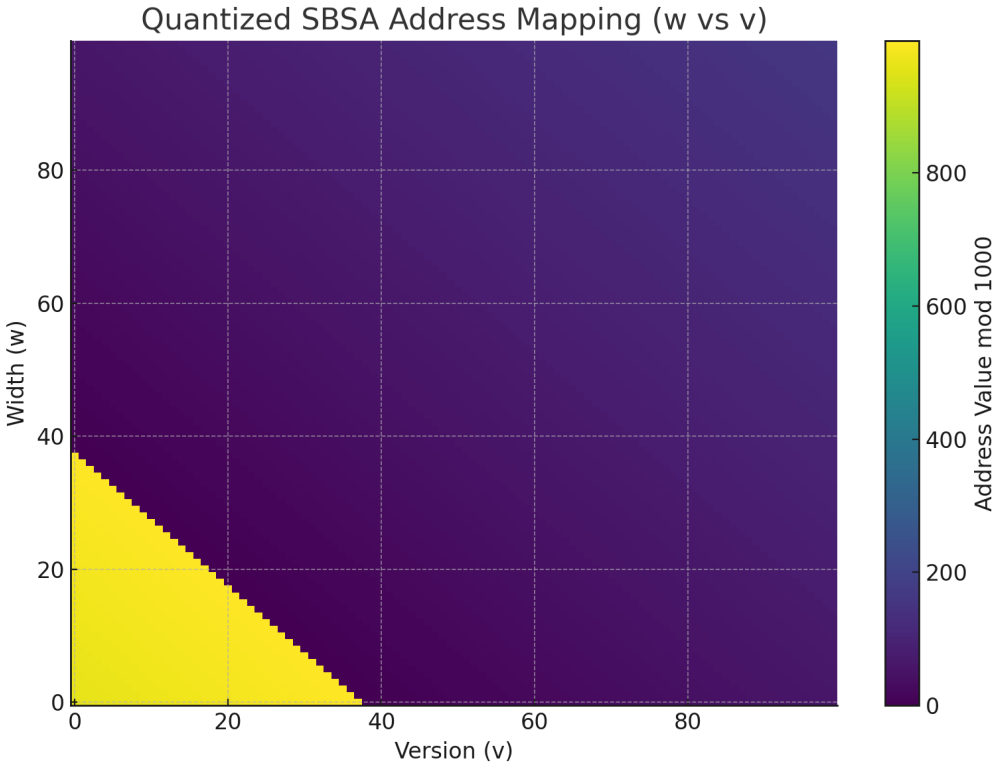

Figure 2: Quantized Address Mapping Heatmap for (w, v) dimensions