The Tetrahedral Engine

A Resolution-Independent Volumetric Rendering System

1. The Core Concept
2.
The **Tetrahedral Engine** is a fundamental reimagining of 3D computer graphics.
For the last 50 years, 3D rendering has relied on the **Cartesian Grid** (X, Y, Z) and **Polygonal Meshes** (triangles). While effective, this approach suffers from a critical flaw: **Aliasing**. When you zoom in, the illusion breaks. Curves become jagged lines, and textures become pixelated blocks.
This engine changes the coordinate system.
Instead of an origin-based point perspective, we utilize a **Skew-Axis Coordinate System** based on the geometry of the Tetrahedron. This allows us to represent 3D volumes not as a stack of flat pictures, but as a continuous, resolution-independent field—similar to a vector file, but for volumetric matter.

2. How It Works

The "Inside-Out" Voxel
Traditional voxels are cubes. They stack poorly and hate rotation.
Our engine uses the **Rhombic Dodecahedron** as its atomic unit.
• **Geometric Dual:** It is the "inside-out" inversion of a Cube.
• **Integer Math:** It maintains a precise 2:1 volume ratio with Cartesian space.
• **Packing:** It tessellates 3D space perfectly with no gaps, like a 3D honeycomb.
The S, T, U Address Space
We replace the standard (X, Y, Z) coordinates with a dimensionless barycentric triplet: (S, T, U).
• S **(Slit 1):** Position along the horizontal edge of the root tetrahedron.
• T **(Slit 2):** Position along the opposing vertical edge.
• U **(Depth):** The barycentric balance between the two axes.
This coordinate system is **Affine Invariant**. You can stretch, squash, or scale the volume to the size of a galaxy, and the internal logic remains perfectly intact without floating-point errors.

3. Key Innovations

1. Exocentric Rendering ("The Hologram")
Standard engines use an **Egocentric** camera (the world revolves around the eye).
The Tetra Engine uses an **Exocentric** model. The object broadcasts light rays in all directions. The "Screen" is just a net that catches these rays.
• **Result:** You can move the screen closer to the object, and the detail increases naturally, exactly like looking closer at a real physical object.
2. The 360° Singularity Solution
X-Slit projection traditionally suffers from "blind spots" (singularities) at 90-degree angles.
We solved this with a **Dynamic Axis Switching** mechanism. The engine automatically detects the view angle and "hands off" the rendering to the optimal pair of tetrahedral edges (Red, Green, or Blue axis pairs), ensuring a seamless, artifact-free image from any angle.
3. Volumetric Compression
By organizing data into a recursive **Tetra-Tree** (similar to an Octree but geometrically superior), we can stream massive 3D assets over the web. The client device can display a low-res "proxy" instantly and fill in the details progressively, enabling "Holographic Streaming."

4. Mathematical Validation

The coordinate system has been mathematically verified via Python simulation.

- **The Round-Trip Proof:** Cartesian points (X,Y,Z) can be converted to Tetra-Space (S,T,U) and back with zero loss of precision.
- **The Center Lock:** The Cartesian origin (0,0,0) maps perfectly to the Tetrahedral center (0.5, 0.5, 0.5).

See /proofs/tetra_validation.py for the validation script.

5. Patent Status

This technology is currently **Patent Pending**.

The unique methods regarding the Rhombic Dodecahedral Voxel derivation, the Skew-Axis rendering pipeline, and the Exocentric viewing model are documented in the associated provisional specification.

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