

## PATENT APPLICATION DRAFT

**Status:** DRAFT (Ready for Provisional Filing)

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### TITLE OF INVENTION

System and Method for Resolution-Independent Volumetric Rendering Using Skew-Axis Tetrahedral Coordinates

### ABSTRACT

A resolution-independent volumetric rendering engine and data structure utilizing a skew-axis coordinate system. The system defines a "Root Tetrahedron" bounded by two opposing non-intersecting slit axes, establishing a dimensionless barycentric address space ( $S, T, U$ ) that replaces orthogonal Cartesian coordinates. Volumetric data is encoded within a recursive spatial hierarchy of Rhombic Dodecahedral voxels, geometrically derived as the inversion of a Cartesian cube, ensuring a precise 2:1 integer volume ratio and seamless integer-math compatibility. This architecture enables an **exocentric rendering model**, where the viewing plane functions as an arbitrary interceptor of the object's continuous ray field. By decoupling the geometric definition from the display resolution, the system eliminates aliasing artifacts, resolves singularity issues via dynamic axis switching, and facilitates the efficient compression and streaming of holographic data.

### TECHNICAL FIELD

The present invention relates generally to computer graphics and volumetric data processing, and more specifically to a non-Cartesian coordinate system for the storage, compression, and rendering of three-dimensional spatial data.

### BRIEF DESCRIPTION OF THE DRAWINGS

- **FIG. 1** illustrates the foundational "Root Tetrahedron" and the dimensionless skew-axis coordinate system ( $S, T, U$ ).
- **FIG. 2** illustrates the recursive subdivision of the volume into a hierarchical spatial tree structure.
- **FIG. 3** illustrates the geometric construction of the Rhombic Dodecahedral Voxel as the dual inversion of a Cartesian Cube.
- **FIG. 4** depicts the "Skewer" ray-casting method and barycentric depth sorting logic.
- **FIG. 5** illustrates the Exocentric Viewing Model, where the display plane intercepts the infinite ray field.
- **FIG. 6** illustrates the Dynamic Axis Switching mechanism used to eliminate geometric singularities during rotation.
- **FIG. 7** is a block diagram of the Codec System Architecture for volumetric streaming.
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### DETAILED DESCRIPTION OF THE INVENTION

#### The Root Volume and Coordinate System (FIG. 1)

The invention defines space via a boundary volume generated by two opposing skew lines, referred to as the **Root Tetrahedron (100)**. Unlike Cartesian systems, this volume is defined by a first edge, the **Horizontal Slit (S-axis)**, and a second opposing edge, the **Vertical Slit (T-axis)**. A volumetric coordinate, or "Ray Address," is established by identifying a point  $S$  along the Horizontal Slit and a point  $T$  along the Vertical Slit. A unique ray is generated by the linear interpolation between these points. Any specific point within the data is located by a third coordinate, **Depth (U)**, which represents the barycentric balance between the two slit axes.

### Recursive Subdivision Hierarchy (FIG. 2)

The system employs a hierarchical data structure (**200**). The Parent Tetrahedron is subdivided into four Child Tetrahedrons and a central Octahedron, which is further subdivided to create a complete set of eight sub-volumes. This subdivision is data-dependent; empty regions are flagged as **Voids**, ensuring sparse traversal and efficient memory usage.

### The Rhombic Dodecahedral Voxel (FIG. 3)

The fundamental volumetric unit is the **Rhombic Dodecahedral Voxel (300)**. As shown in **FIG. 3**, this shape is derived as an "inside-out" inversion of a Cartesian Cube. The vertices of the Rhombic Dodecahedron correspond to the extruded center point of the cube through its faces. This relationship results in a precise integer volume ratio of **2.0:1** relative to the inscribed cube, allowing for integer-based arithmetic without floating-point errors.

### Ray-Casting Logic (FIG. 4)

Rendering is performed via the "**Skewer" Method (400)**. A viewing ray defined by coordinates (**S, T**) queries the spatial tree. The system recursively descends through Bounding Volumes until a Leaf Node is identified. Depth sorting is intrinsic to the **U**-coordinate, eliminating the need for a separate Z-buffer sort.

### Exocentric Viewing Model (FIG. 5)

The system utilizes an **Exocentric Model (500)** where the "camera" is an external **Intercept Plane**. The Root Tetrahedron acts as a volumetric emitter. The Intercept Plane captures a subset of the infinite ray field based on its position, allowing for resolution-independent zooming and parallax effects without re-meshing the source object.

### Singularity Avoidance (FIG. 6)

To address the geometric singularity inherent in linear X-slit projection, the system employs a **Multi-Chart Projection (600)**. The 3D field is divided into three primary zones corresponding to the three orthogonal edge pairs of the tetrahedron. As the view vector rotates, the system dynamically "hands off" the rendering responsibility to the optimal edge pair, ensuring 360-degree coverage.

## CLAIMS

### 1. A method for encoding three-dimensional volumetric data, comprising:

Defining a root bounding volume as a tetrahedron established by two opposing, non-intersecting skew axes designated as a first slit (**S**) and a second slit (**T**);  
Addressable spatial points within said volume being defined by a triplet of barycentric coordinates (**S, T, U**), wherein **S** represents a position along the first slit, **T** represents a position along the second slit, and **U** represents a ratio of influence between the first and second slits.

### 2. The method of Claim 1, wherein the coordinate system is affine-invariant, such that the volumetric data remains topologically valid under linear deformation, stretching, or shearing of the root tetrahedron vertices.

### 3. The method of Claim 1, further comprising a recursive subdivision scheme wherein the root tetrahedron is decomposed into a hierarchy of sub-tetrahedra and octahedra, forming a spatial tree structure.

### 4. A volumetric data structure comprising a plurality of voxels, wherein each voxel defines a volume having the geometry of a Rhombic Dodecahedron, said geometry being derived as the geometric dual of a face-centered cubic lattice, having a volume exactly twice that of its inscribed Cartesian cube.

### 5. A volumetric codec system comprising:

An encoder configured to map Cartesian input data into the skew-axis coordinate system of Claim 1;

A transmission layer configured to stream said data as a hierarchical bitstream;

A decoder configured to reconstruct the volumetric tree progressively, prioritizing root nodes before leaf nodes to enable resolution-independent playback.

- 6.** The system of Claim 5, utilizing an exocentric rendering model wherein a viewing plane is defined as an arbitrary planar intercept of the ray field emanating from the root tetrahedron.
- 7.** The system of Claim 5, further comprising a dynamic axis-switching mechanism configured to detect a view angle relative to the skew axes and switch the active coordinate definition to an orthogonal pair of tetrahedral edges to prevent geometric singularity.
- 8.** A non-transitory computer-readable medium storing instructions that, when executed, cause a processor to render an image by determining a ray path defined by a first point on a horizontal slit edge and a second point on a vertical slit edge, and sampling volumetric data along said path based on a depth ratio (U).

SIGNATURE OF INVENTOR

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