Sirkata: A Scalable Server for 3D Metaverses

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Motivation
Metaverses are virtual worlds where any user can add objects and script their behavior.

Scripting Object Behavior
Users script in Emerson, a JavaScript-based programming system that designed for virtual world application development.

Data model
- Multi-presencing - Allows a single script to control many objects in the virtual world.
- Sandbox - Language-level sandboxing allows objects and avatars to execute code from others they do not trust.

Conditioning User Content for Delivery
Content must be conditioned into a format suitable for real-time rendering and network delivery.

Conditioning Goals
- Reducing Draw Calls
- Simplifying Mesh
- Reducing Texture Space
- Progressive Transmission

Conversion Process
1. Clean and normalize
2. Break the model into charts, contiguous submeshes used to map the mesh into a texture
3. Fairly allocate texture space to charts
4. Pack charts into a texture atlas
5. Simplify the model
6. Encode in a progressive, streamable format

Delivery Format
- Base, low-resolution version of the model
- Additional vertices streamed via a progressive mesh format
- Higher resolution textures (mipmaps) downloaded for additional texture resolution

Object Aggregation for Complete Views
Solid angle queries alone can miss large collections of small objects, so Sirkata aggregates objects using the LBVH:
- Each internal node represents an aggregate
- Assigned object identifier; meshes are combined, simplified, and stored on the CDN
- Cut gives complete view of world, some at lower quality
- Only visual placeholders; objects cannot communicate with them

Forwarder: Geometric Congestion Control
- Forwarder enables inter-object communication
- Physically-motivated falloff function gives high weight to nearby & large objects
- Guaranteed minimum quality of service for each pair of objects

Implementation
- Based on Core Stateless Fair Queueing
- Handle weights that vary by orders of magnitude
- Minimize per-flow state with 3 stage, cross-server queue design

For efficient download and display:
- LBVH groups similar objects using Zernike shape descriptors computed by the CDN
- Shared geometry and textures stored once per aggregate
- "Instance-aware" simplification exploits redundancy in aggregates, tracking the effect of each submesh edge on the overall mesh and only collapsing submesh edges

For federated virtual worlds, Sirkata replaces distance queries with solid angle queries, returning objects covering many pixels. Queries are global because large, distant objects can satisfy the query. A novel modification to Bounding Volume Hierarchies, the LBVH, makes them scalable and efficient.