Virtual Drone View: Real-time Single-frame Point Cloud to Colored Mesh Reconstruction

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Problem Statement

Remote operation of heavy machinery suffers from limited depth perception, which reduces spatial awareness and increases operational risk[1]. Existing mesh reconstruction methods cannot meet the strict latency and single-frame constraints required for a real-time virtual drone view. This project addresses the need for a fast and reliable pipeline that converts each RGB-D frame into a coherent colored mesh suitable for immediate operator use.

Fig. 1 Comparison between traditional 2D operator display and 3D virtual drone view

Concept Generation

To enable real-time virtual drone teleoperation, the system is organized into three functional modules.

1. Camera Module: Capture point cloud data at ≥10 FPS.
2. Reconstruction Module: Produce a 3D mesh within ~100 ms.
3. Visualization Module: Render the colorized 3D mesh for viewing.

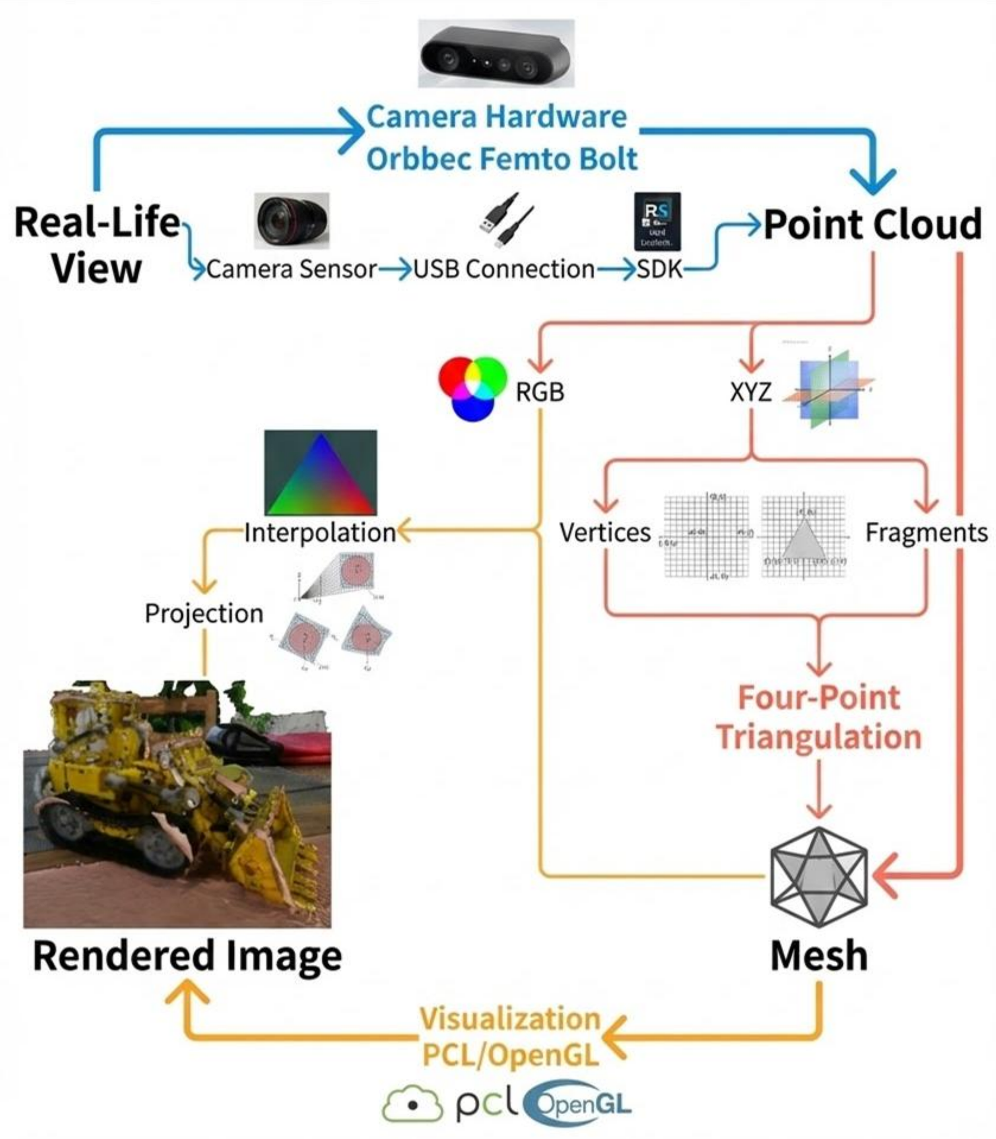

Fig.2 Concept Diagram

Design Description

Camera Module

A RGB-D time-of-flight camera is used to capture single aligned depth–color frame and convert it into organized point cloud.

Reconstruction Algorithm

This frame is processed through a fast triangulation module that builds a lightweight surface mesh in real time. Filtering steps remove invalid points, limit depth jumps, and patch small gaps to maintain surface continuity.

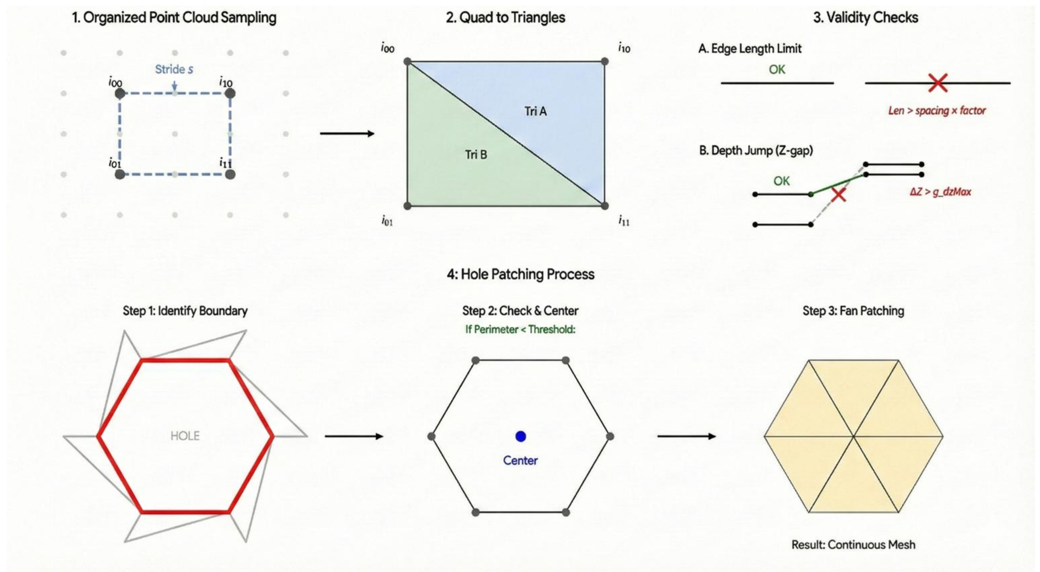

Fig.3 Mesh Construction & Hole Patching

Visualization Module

The colored mesh is then sent to an OpenGL viewer, which renders a stable drone-view of the scene on the laptop with low latency suitable for teleoperation.

GPU Acceleration

Compared with the CPU-based algorithm, which uses two nested for-loops to iterate through the whole point cloud, the GPU-based algorithm features much more parallelism by considering every four neighboring points at the same time, so the reconstruction process is much faster. Also, the vertices and indices of the reconstructed mesh are sent to the OpenGL buffers on the GPU directly to avoid repeated data transmissions between the CPU and the GPU.

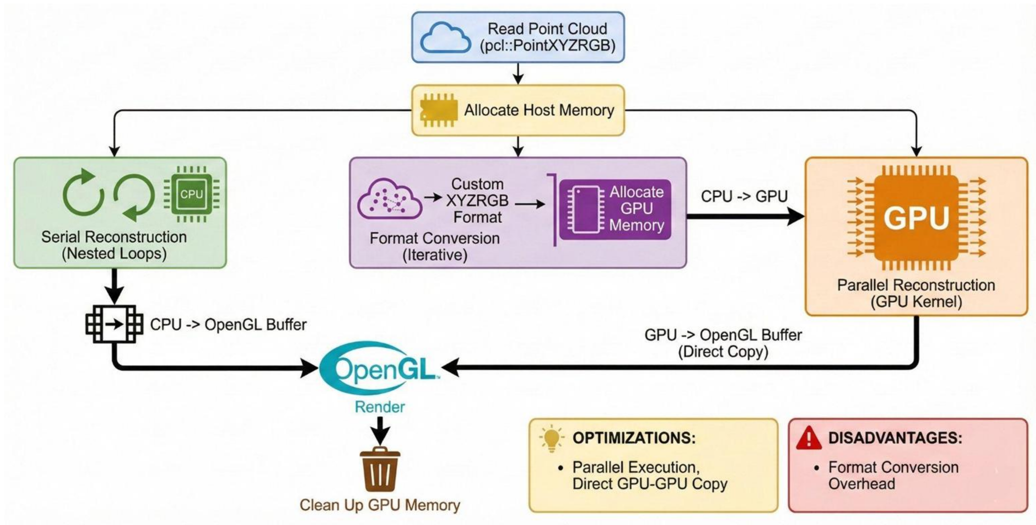

Fig. 4 GPU Acceleration Architecture

Validation

Performance was validated on frame rate, reconstruction latency, and visual scene intelligibility via Orbbec SDK logs, timestamp profiling, and human perceptual evaluation against a reference RGB photo, with ≈50 participants viewing plain/minimal-object scenes and scored using $N_{pass}/N_{total} \times 100\%$, where a pass is defined as ≥3/4 “Yes” ratings across layout, depth, boundary clarity and motion.

✓ Frame rate ≥ 10 FPS (SDK log)
✓ Reconstruction latency ≈ 100 ms average (timestamped)
✓ Visual Scene Intelligibility ≥ 85% pass rate
✓ Total expenditure ≤ ￥4000
✓ Equipment: Femto Bolt, laptop

Conclusion

The project delivers a real-time virtual drone view system that transforms single-frame point clouds into colored meshes with low latency. Through efficient triangulation and optimized GPU rendering, the system meets key performance targets for speed and perceptual clarity. The resulting prototype offers enhancement to remote teleoperation by improving operator depth understanding and situational awareness.

Acknowledgement

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Reference

[1] T. Tanimoto, K. Shinohara, H. Yoshinada. “Research on effective teleoperation of construction machinery fusing manual and automatic operation”. In: Robomech Journal 4.1 (2017), p. 14. DOI: 10.1186/s40648-017-0082-3.