Combining LiDAR Point Clouds with VR Display Technologies – Towards Rapid Virtual Replication of Real World Environments

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VE Group History

• Formerly the “Living Environments Laboratory”
  • Formed at start of research institute (2010)
  • Patti Brennan – former Director

• 2013 - R01 AHRQ Grant – vizHOME
  • Better understand how home context affects management of health and health information inside of the home environment

• 2016 – “re-branded” to Virtual Environments Group
Motivation

- Study any home environment within VR
- Real spaces:
  - Have a lot of clutter and objects
  - All of this is very hard to 3D model
  - Time consuming
  - Varying lighting conditions
- Solution? – Terrestrial LiDAR?
- Light Detection and Ranging
- Combine LiDAR point clouds with VR Display technology!?
Our LiDAR Scanner

- Faro Focus S120 – 2013
- 360 horizontal, 300 vertical FOV
- # points per scan: 5 – 760 million
- Time: 4 minutes – 2+ hours
- Weight: 11 pounds
- Used to scan 20 home interiors in South Central Wisconsin for vizHOME (2014-2015)
- Currently being used again, for home interiors, 6 of 30 (2019-2020).
## Data Pipeline

<table>
<thead>
<tr>
<th>Pipeline Step</th>
<th>Time</th>
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<tbody>
<tr>
<td>1. Scan a Physical Space – 44 million points, 7 mins per scan</td>
<td>(2 - 4 hours)</td>
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<tr>
<td>2. Import FARO SCENE (Registration, Filtering, Cleanup)</td>
<td>(2 - 3 hours)</td>
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<tr>
<td>3. Export to XYZ</td>
<td>(15 - 30 mins)</td>
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<tr>
<td>4. Custom Processing Tool (Octree + Compression)</td>
<td>(15 mins – 1 hour)</td>
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<td>5. Visualization:</td>
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- **Total Time ~ 5-8 hours**
Mesh vs. Point Cloud

Mesh

Pointcloud

Point clouds retain details about the scene
Prior Work


• Only other prior LiDAR + CAVE work?

• Geology Applications

• Linux – VRUI

• We run Windows - so wanted to take a new approach
Problems w/ LiDAR Data

• Size of data sets (20 GB +)
• # of point primitives per frame (Geometry Bound)
• Uneven density of points
• Point Size / Rendering Techniques
• Mirrors / Reflections
Initial Work


• Octree data structure
  • Points within octants
  • Frustum cull bounds of octants

• Out of Core Loading
  • Relaxes data size problem

• But….  
  • # of point primitives still a challenge
  • Uneven sampling causes varying number of points rendered in different areas = inconsistent frame rates
Next Step - Image Warping

- Re-use points from last frame + Add additional streaming points
- 1 point per pixel approach
Current State

• Combines parts from each previous work
• Adds improvements to depth artifacts
• Come try it out at the conference!

• Have created various interaction techniques and one-off versions for specific research applications
  • Painting (Highlighting) with colors
  • Selecting bounded objects
  • Combined 360 imagery from LiDAR scanner with point cloud (swap to 360 image when walking onto scan location)
  • Audio narratives
  • “Physics”
Additional Applications

• Crime Scene Investigation
• Cultural Heritage
• New Mexico Cave Visualization
• Shipwreck Reconstruction
• Landscape Architecture
• Home Modifications
Crime Scene Investigation
Cultural Heritage
Shipwreck Reconstruction

- Different source data – underwater camera rigs
- Photogrammetry – Agisoft Photoscan
- Same tools for rendering point cloud exports
Next / Future Directions

• Patent / Unity Plug-In
• Lower Cost 3D Scanners
• Kinect Azure Scanner?
• Home Modifications
• 4D Immersive Point Clouds?
• Auto-segmentation of objects
• In-Painting of scenes?
• More applications!
Conclusions

• Point Cloud rendering in VR is hard
• We’ve developed a solution that works and achieves acceptable frame rates (40-80 fps) for VR
• Loading speed vs. frame rate trade-off
• Do you use LiDAR data – for what applications?
• What do you use for rendering?
• Let’s discuss further!
Thank you!

- [https://virtualenvironments.discovery.wisc.edu](https://virtualenvironments.discovery.wisc.edu)
- [https://vizhome.org](https://vizhome.org) – large home point clouds for download and example playback videos (new ones soon)!
- [https://3d-csi.discovery.wisc.edu](https://3d-csi.discovery.wisc.edu)
- Kevin Ponto, Simon Smith
- The CAAV
- Indiana University
- Questions?