



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

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CAAV 2019

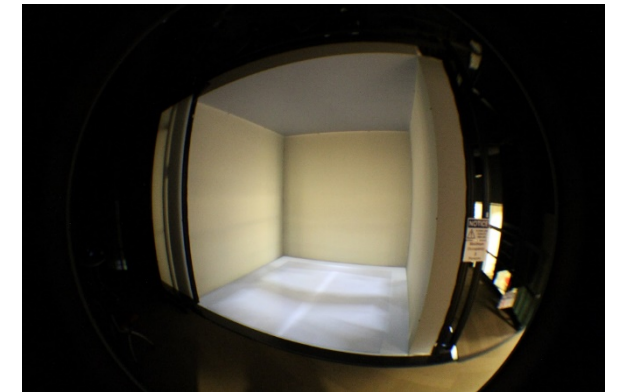
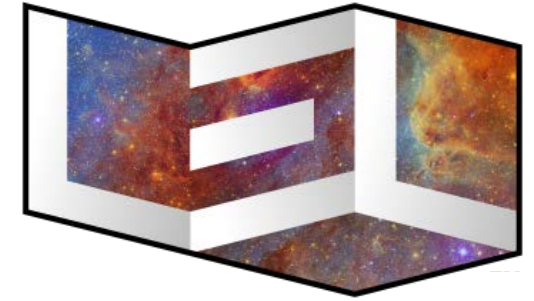


Wisconsin Institute for Discovery



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

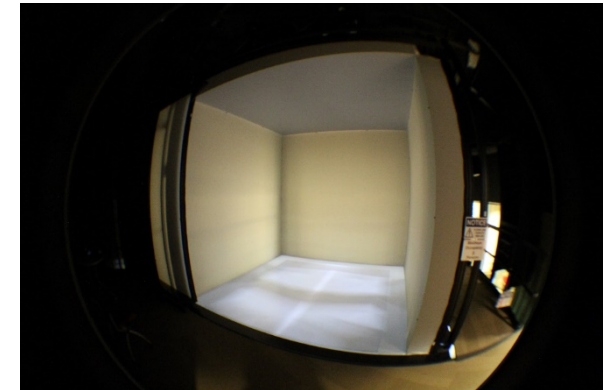


Motivation

- 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?
- **L**ight **D**etection and **R**anging
- Combine LiDAR point clouds with VR Display technology!?



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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

Pipeline Step

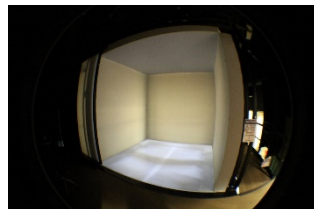
1. Scan a Physical Space – 44 million points, 7 mins per scan

2. Import FARO SCENE (Registration, Filtering, Cleanup)

3. Export to XYZ

4. Custom Processing Tool
(Octree + Compression)

5. Visualization:



Time

(2 - 4 hours)

(2 - 3 hours)

(15 - 30 mins)

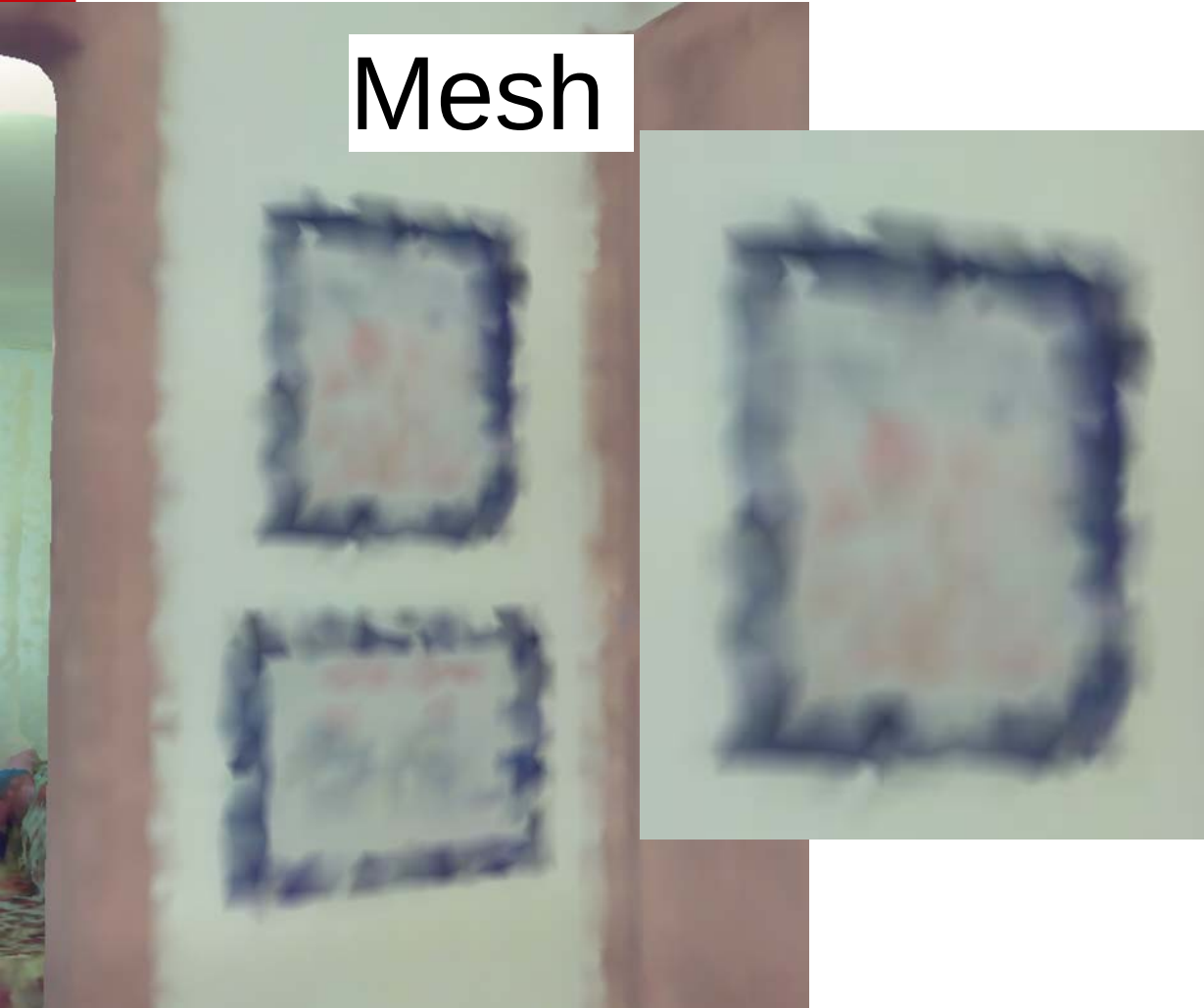
(15 mins – 1 hour)

• Total Time ~ 5-8 hours

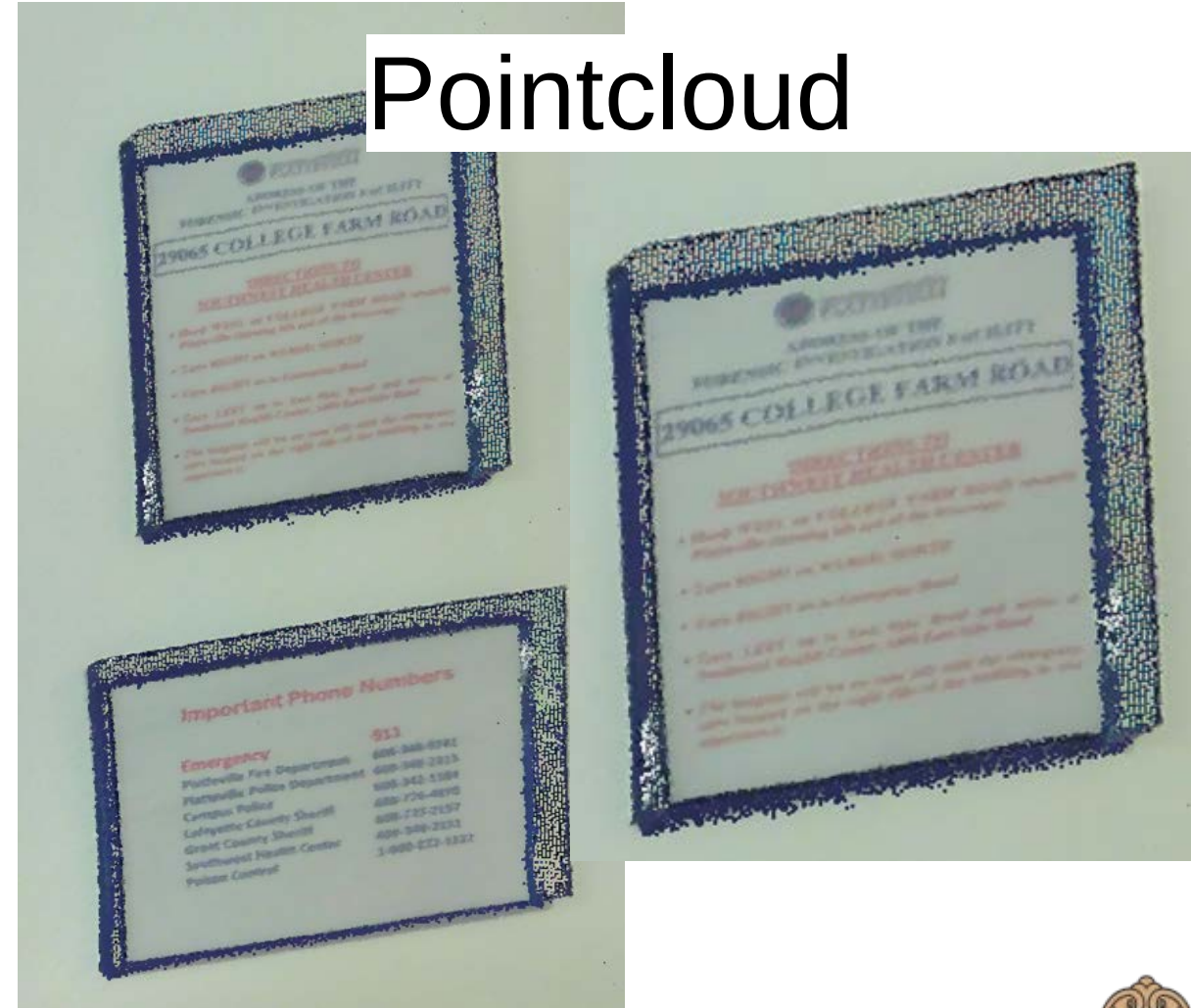


Mesh vs. Point Cloud

Mesh



Pointcloud

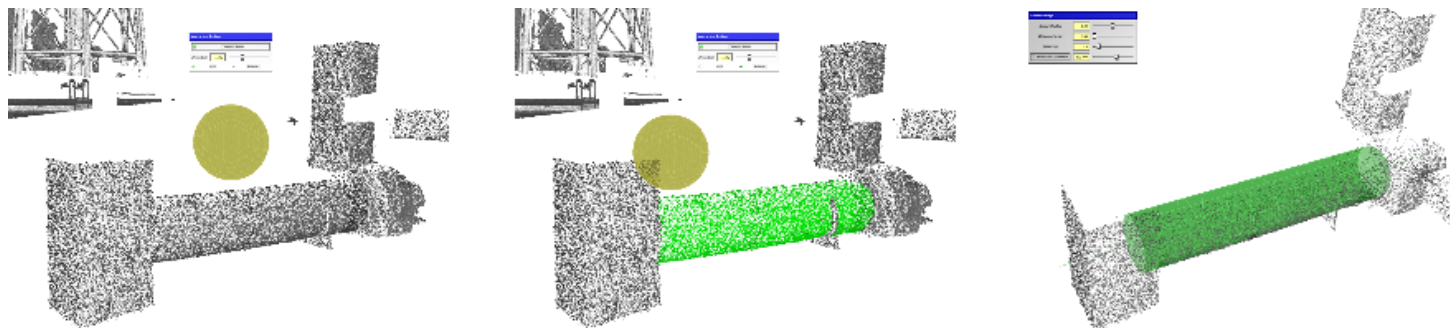


Point clouds retain details about the scene



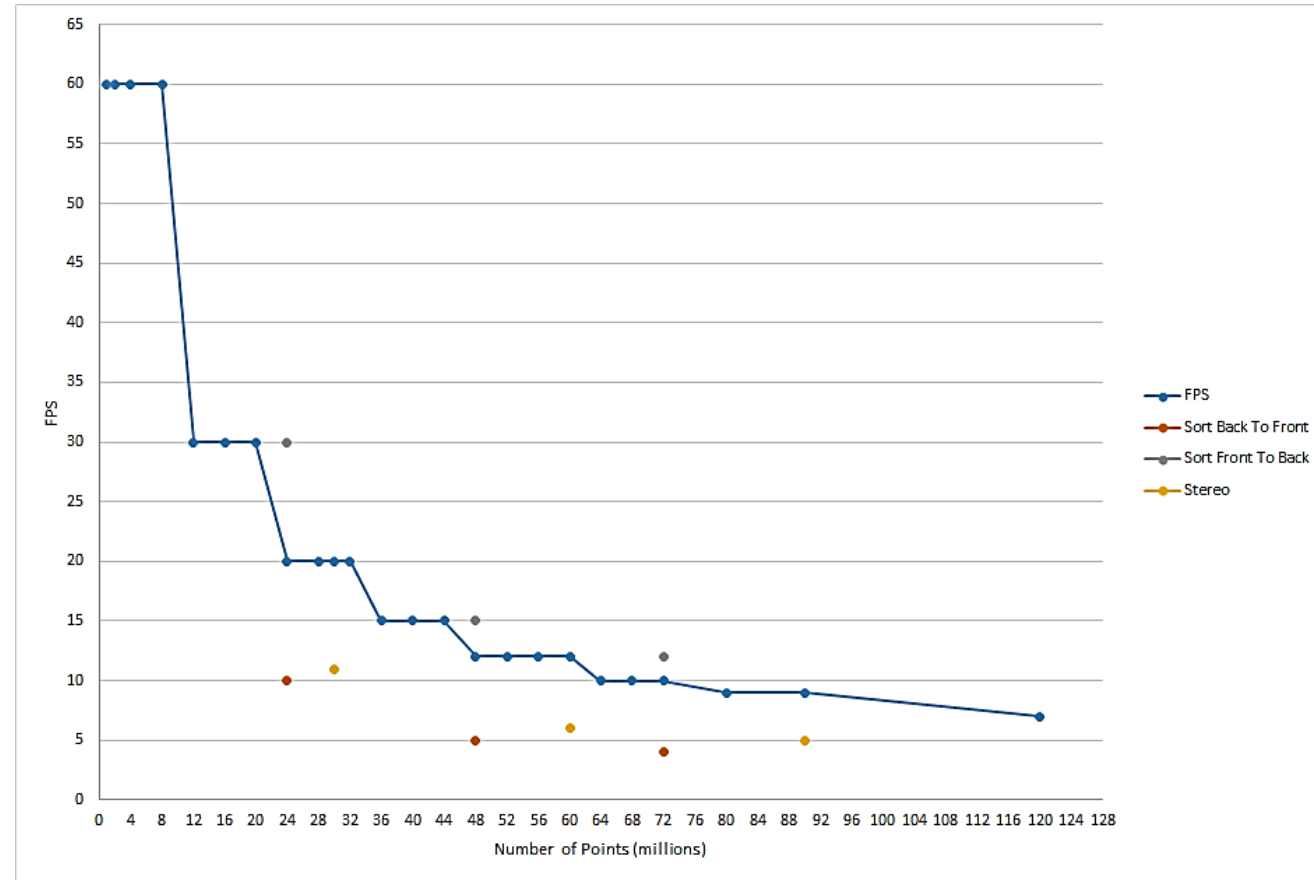
Prior Work

- Kreylos, O., Bawden, G. W., & Kellogg, L. H. (2008, December). Immersive visualization and analysis of LiDAR data. In *International Symposium on Visual Computing* (pp. 846-855). Springer, Berlin, Heidelberg.
- 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



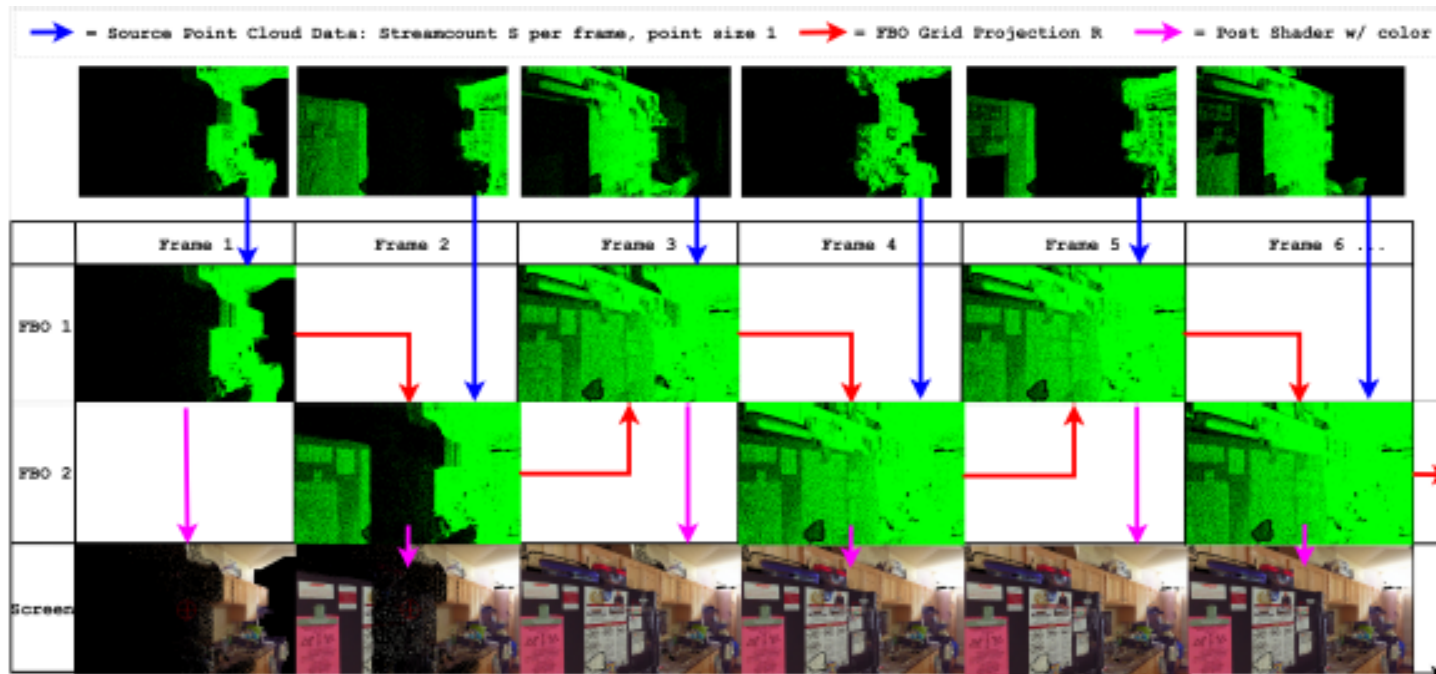
Initial Work

- Tredinnick, R., Broecker, M., & Ponto, K. (2015, March). Experiencing interior environments: New approaches for the immersive display of large-scale point cloud data. In *2015 IEEE Virtual Reality (VR)* (pp. 297-298). IEEE.
- 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
- Tredinnick, R., Broecker, M., & Ponto, K. (2016, March). Progressive feedback point cloud rendering for virtual reality display. In *2016 IEEE Virtual Reality (VR)* (pp. 301-302). IEEE.



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

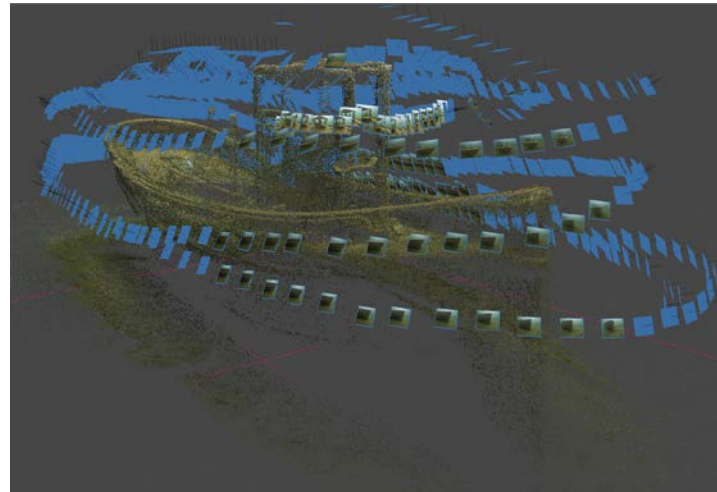
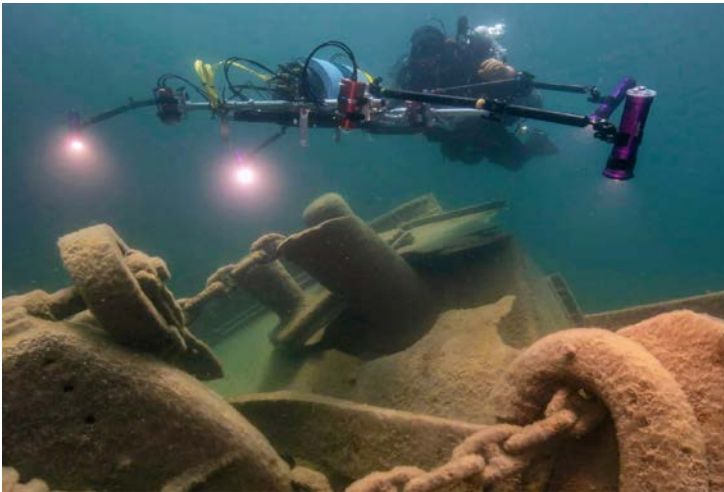
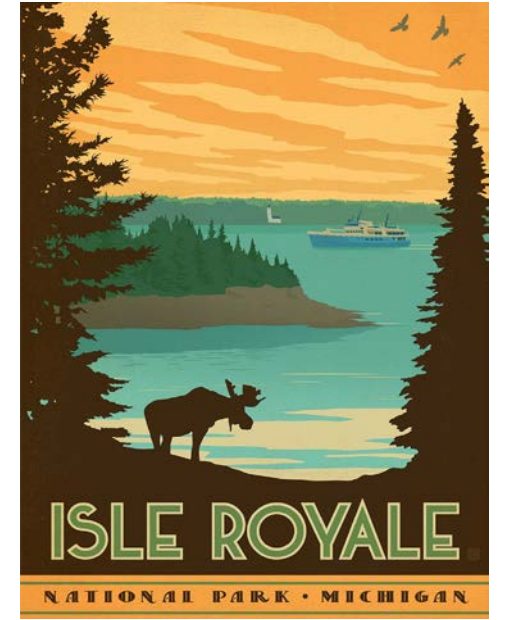


Cultural Heritage



Shipwreck Reconstruction

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



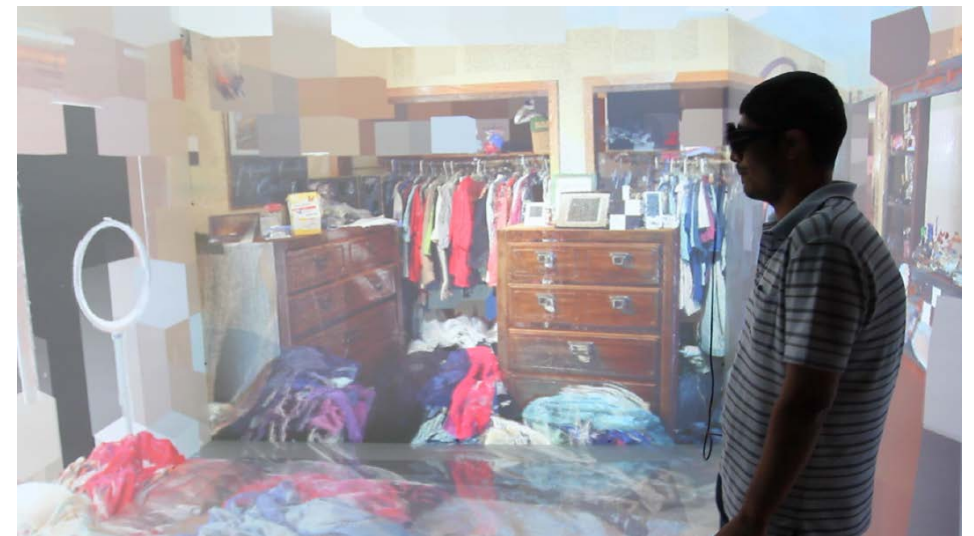
Next / Future Directions

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

