



Analytical and Computer Cartography Winter Quarter 2017

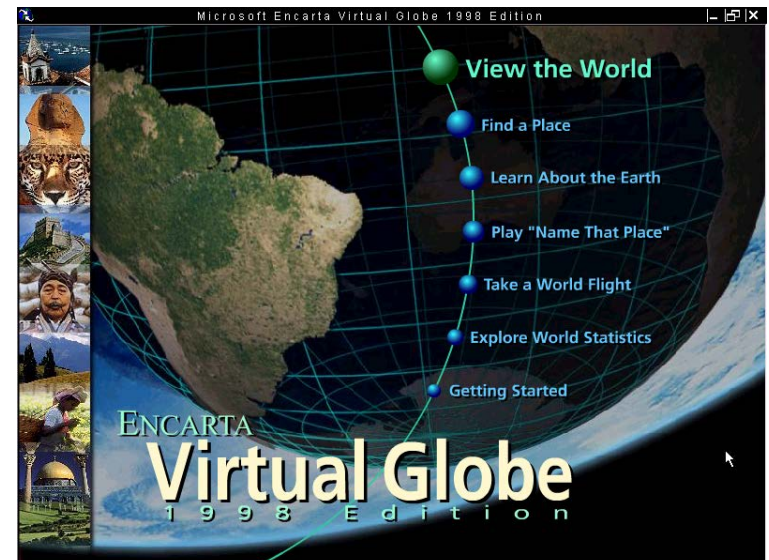
## Lecture 15:

# Technical Issues for 3D rendering

# Virtual Globes: Wikipedia

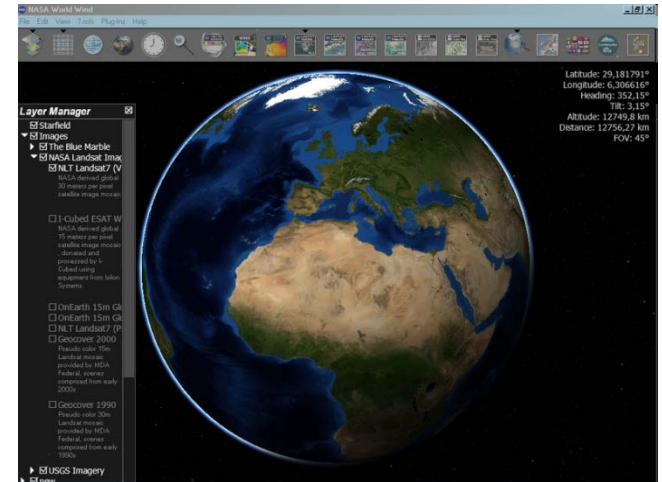
- A 3D software model or representation of the Earth or another world.
- Provides the user with the ability to freely move around in the virtual environment by changing the viewing angle and position.
- Can represent many different views on the surface of the Earth: geographical features, man-made, abstract representations of demographic quantities such as population.

- In 1998, Microsoft released a popular offline virtual globe in the form of Encarta Virtual Globe 98
- First widely publicized online virtual globes were NASA World Wind (released in mid-2004) and Google Earth (mid-2005)



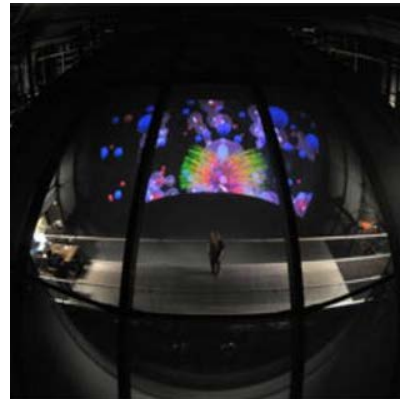
# Examples

- [NASA World Wind](#)\*
- [CitySurf Globe](#)
- [Bing Maps](#)
- [SkylineGlobe](#)
- [Google Earth](#)
- [Marble](#), part of the [K Desktop Environment](#), with [OpenStreetMap](#)\*
- [ArcGIS Explorer](#)
- [EarthBrowser](#)
- [Software MacKiev's 3D Weather Globe & Atlas](#)
- [Earth3D](#)\*
- [WorldView](#)
- [Bhuvan](#)



# Virtual Geographic Reality

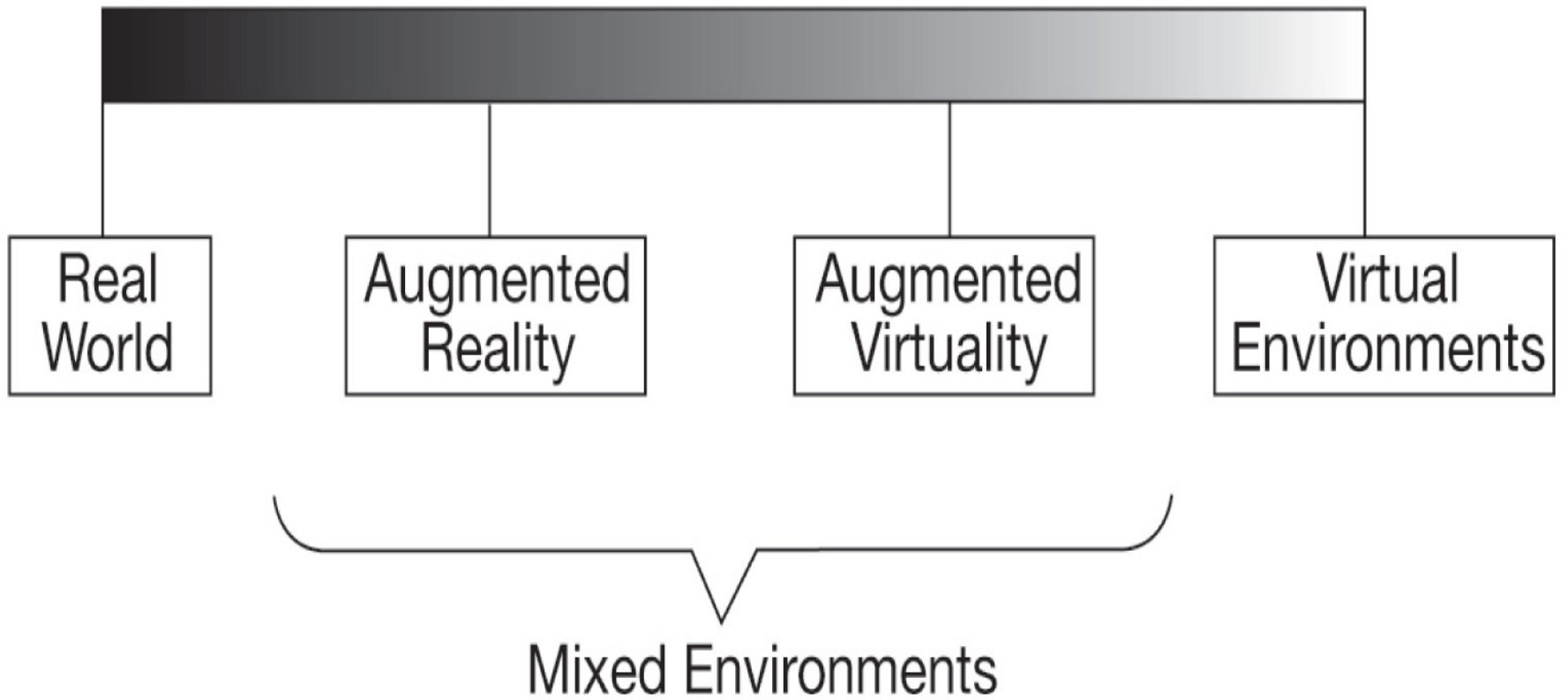
- Immersive Virtual reality
- Personal virtual reality
- Group immersion environments
- Web-based virtual reality
- Augmented reality



# Google Cardboard (\$15)



# Reality-Virtuality Continuum



# Some history

- Mid 1950s, visionary cinematographer Morton H. Eilig built a single user console called Sensorama
  - stereoscopic display
  - Fan emitters
  - stereo speakers
  - moving chair
- 1961, Philco Corporation developed the first HMD the “Headsight.”
  - helmet had a video screen and tracking system.
  - linked to a closed circuit camera system
  - used for helicopter pilots
- In 1965, Ivan Sutherland envisioned what he called the “Ultimate Display.”
  - During 1966, Sutherland built a tethered VR system

# Sensorama and Headsight

Introducing . . .

## sensorama

The Revolutionary Motion Picture System that takes you into another world with

- 3-D
- WIDE VISION
- MOTION
- COLOR
- STEREO-SOUND
- AROMAS
- WIND
- VIBRATIONS



Ⓞ PATENTED

SENSORAMA, INC., 855 GALLOWAY ST., PACIFIC PALISADES, CALIF. 90272  
TEL. (213) 459-2162





# Sutherland (1965) Flight Simulator



## A HEAD-MOUNTED THREE-DIMENSIONAL DISPLAY\*

Ivan E. Sutherland

\* The work reported in this paper was performed at Harvard University, supported in part by the Advanced Research Projects Agency (ARPA) of the Department of Defense under contract SD 265, in part by the Office of Naval Research under contract ONR 1866 (16), and in part by a long standing agreement between Bell Telephone Laboratories and the Harvard Computation Laboratory. The early work at the NUT Lincoln Laboratory was also supported by ARPA.

### Introduction

The fundamental idea behind the three-dimensional display is to present the user with a perspective image which changes as he moves. The retinal image of the real objects which we see is, after all, only two-dimensional. Thus if we can place suitable two-dimensional images on the observer's retinas, we can create the illusion that he is seeing a three-dimensional object. Although stereo presentation is important to the three-dimensional illusion, it is less important than the change that takes place in the image when the observer moves his head. The image presented by the three-dimensional display must change in exactly the way that the image of a real object would change for similar motions of the user's head. Psychologists have long known that moving perspective images appear strikingly three-dimensional even without stereo presentation; the three-dimensional display described in this paper depends heavily on this "kinetic depth effect". (1)

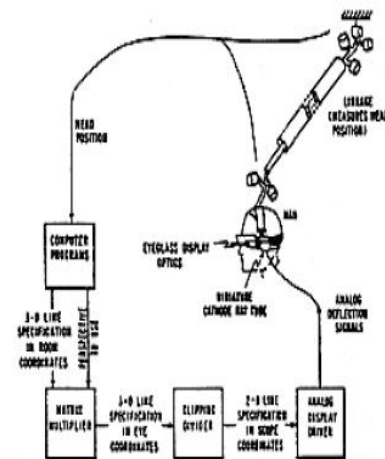


Figure 1: The parts of the three-dimensional display system

# True VR: Immersive, interactive, multi-sense



# How does it work?

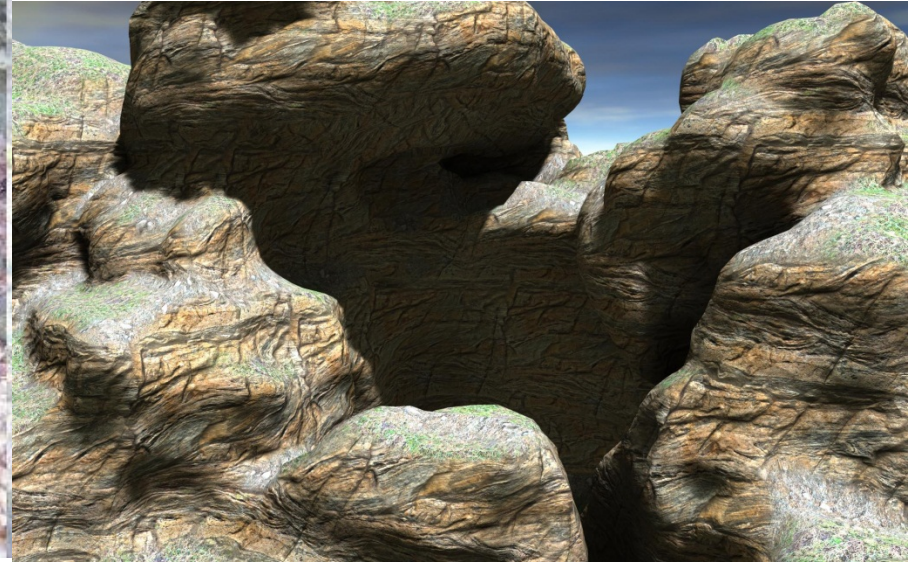


- Synchronized sound and video
- Stereo separation by isolated lenses
- Head movement sensing
- Reduced frame and interaction lag

# Some issues in 3D rendering

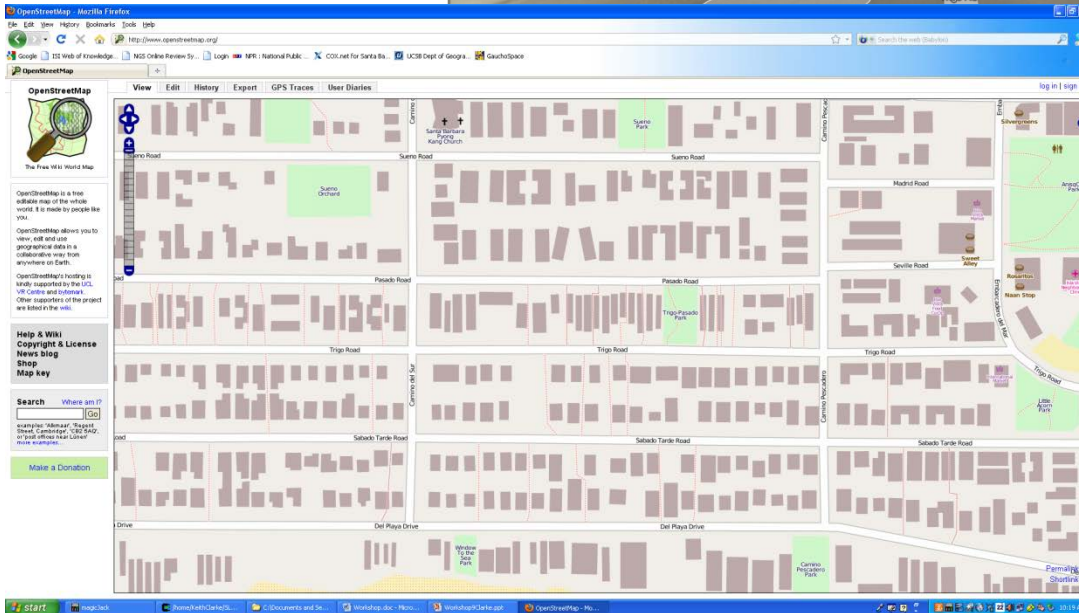
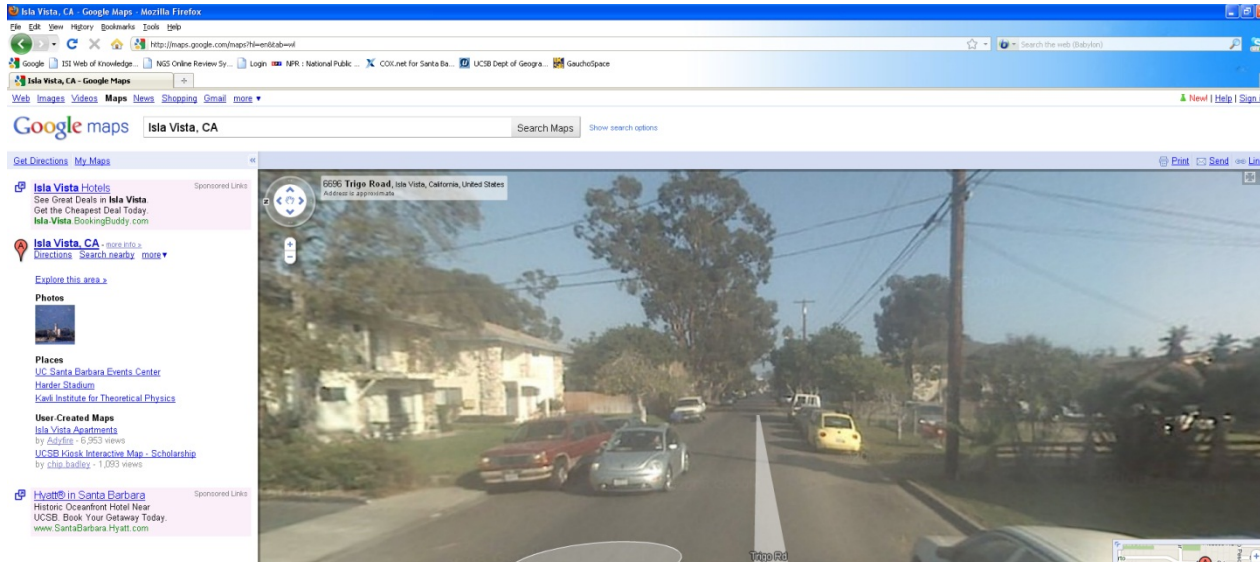
- Level of Detail and map generalization
- Media and devices
- Image cross registration: geometry
- Interactivity
- Tools
- Realism: Differs in 2D, 3D, AR and VR
- Virtual environment vs. reality
- Models

# Realism and human perception





# Streetview vs. Openstreetmap



# Modeling issues in a 3D World

- Cartographic Generalization
- Level of Detail
- 3D measurement systems
- 3D modeling and data structures
- 3D standards for Geospatial data
- Open Source Programming Libraries
- 3D in Geobrowsers (Google Sketch-up, Earth and Bing Maps)



# Generalization in Cartography

- Selection
- Simplification
- Combination
- Displacement
- Exaggeration



# GIS: Scale Range Viewing

The screenshot displays the ArcView GIS 3.2 interface. The main window shows a globe with a red grid overlay. The legend editor window is open, showing a table with columns for Symbol, Value, Label, and Count. The table contains four rows of data:

Symbol	Value	Label	Count
	1	1	
	2	2	
	7	7	
	10	10	

The legend editor window also shows the following settings:

- Theme: Persp.dxf
- Legend Type: Unique Value
- Values Field: Color
- Color Schemes: Bountiful Harvest

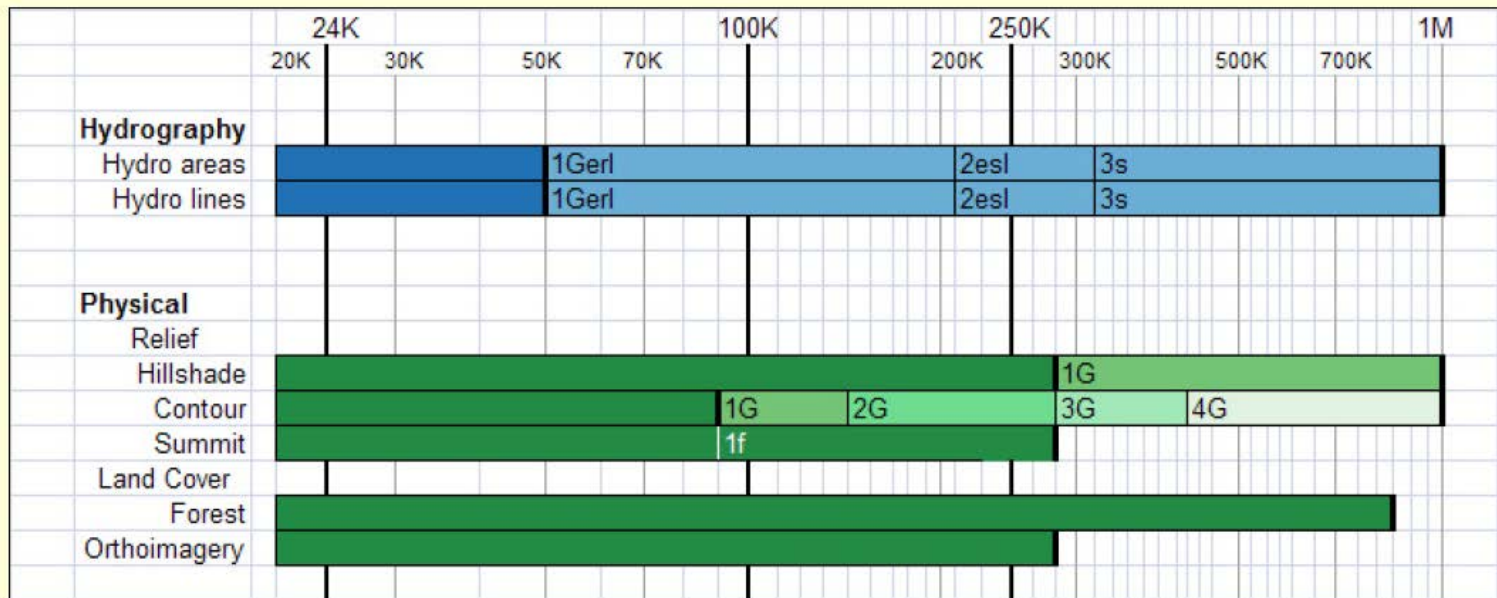
The Advanced Options window is also open, showing the following settings:

- Line Offset: 0
- Scale Symbols:
- Reference Scale: 1: 5736440

The main window shows a globe with a red grid overlay. The scale is 1:5,736,439. The legend editor window is open, showing a table with columns for Symbol, Value, Label, and Count. The table contains four rows of data:

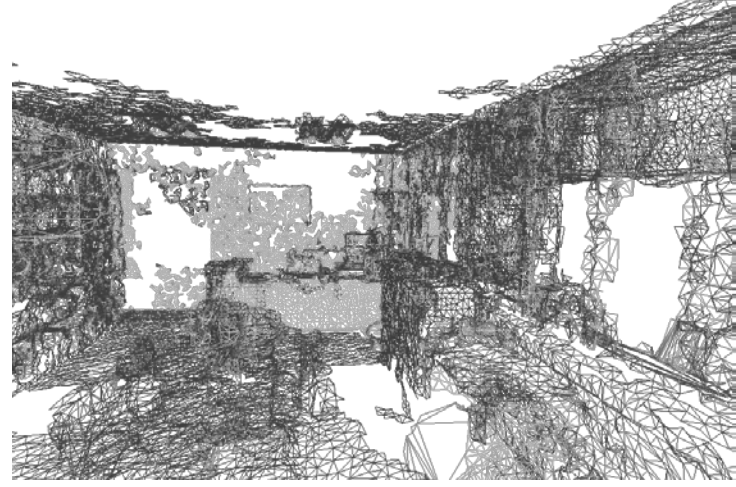
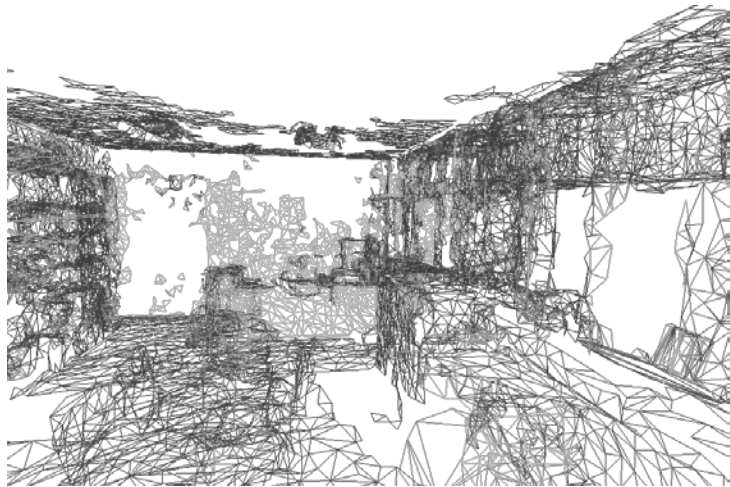
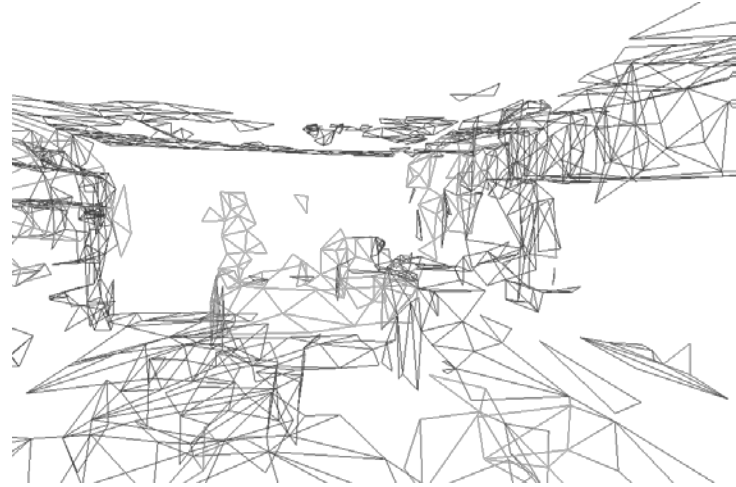
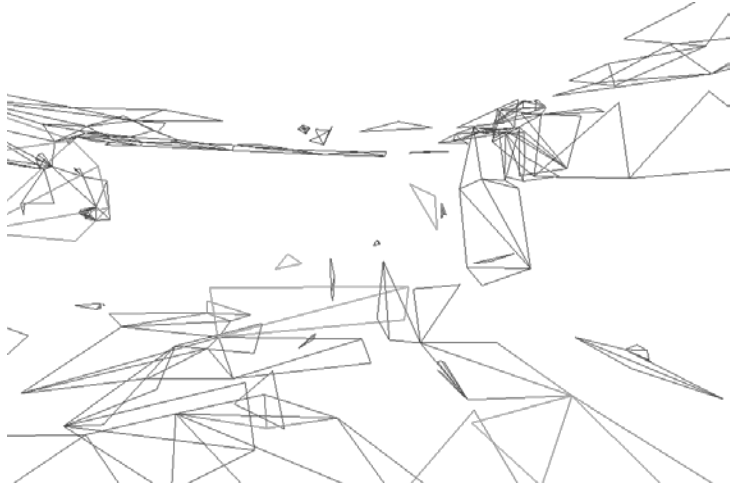
# Scalemaster (Buttenfield and Brewer)

## Case Study: Multi-Scale Hydrography





# Generalization and LOD



# LoD demonstration tools

- Meshlab
- Simplygon
- Vizup
- Rational Reducer
- Pro Optimizer
- OpenSG



# VRML 2.0 LOD Example

```
#VRML V2.0 utf8
```

```
LOD { range [20,40] level [
```

```
#full detail 16 sided cone
```

```
Shape{ appearance Appearance { material Material { diffuseColor 1.0 1.0 1.0 } }  
geometry Extrusion{ crossSection [ -1 0, 0 0, -1 -2 -1 0]  
spine [1 0 0 , 0.866 0 0.5, 0.5 0 0.866, 0 0 1 , -0.5 0 0.866, -0.866 0 0.5, -1 0 0, -  
0.866 0 -0.5, -0.5 0 -0.866, 0 0 -1 , 0.5 0 -0.866, 0.866 0 -0.5, 1 0 0 ] } }
```

```
#intermediate detail 8 sided cone
```

```
Shape{ appearance Appearance { material Material { diffuseColor 1.0 1.0 1.0 } }  
geometry Extrusion{ crossSection [ -1 0, 0 0, -1 -2 -1 0]  
spine [1 0 0 , 0.707 0 0.707 , 0 0 1 , -0.707 0 0.707, -1 0 0,-0.707 0 -0.707, 0 0 -1 ,  
0.707 0 -0.707, 1 0 0 ] } }
```

```
#low detail 4 sided cone
```

```
Shape{ appearance Appearance { material Material { diffuseColor 1.0 1.0 1.0 } }  
geometry Extrusion{ crossSection [ -1 0, 0 0, -1 -2 -1 0]  
spine [1 0 0 , 0 0 1, -1 0 0, 0 0 -1 , 1 0 0 ] } }  
]  
}
```



# 3D measurement systems

- First generation DEMs, photogrammetry and contour conversion
- Second generation based on SAR and IFSAR
- SRTM near global coverage, 30m/90m
- NED completed at 30m, then 15m+
- LIDAR now taking over
- New variants on LiDAR (Flash, Full waveform)
- IR mapping e.g. Microsoft Kinect
- Camera systems: image to 3D model



# Software (See: wiki entry)

- 3dsmax
- AC3D
- Ayam
- AOI
- Blender
- Carrara
- Cheetah 3D
- Cinema 4D
- CityEngine
- Cobalt
- Electric Image Animation System
- Form-Z
- Houdini
- Hypershoot
- Hypermove
- Lightwave3D
- MASSIVE
- Maya
- Modo
- plugin3D
- POV-Ray
- Pro/Engineer
- Quest 3D creative
- Quest 3D Power
- Quest 3D VR
- Relux Professional
- Rhinoceros 3D
- Silo
- SketchUp/Pro
- Softtimage
- Solid Edge
- solidThinking
- SolidWorks
- Swift3D
- trueSpace
- ViewBuild3D
- VR4MAX
- Vue
- ZBrush

# 3D standards for Geospatial data

- VRML and GeoVRML
- X3D and OGC, Geospatial component and X3D Earth (e.g. Planet9 London)
- OGC CityGML
- Web3D Service
- [LandXML.org](http://LandXML.org)
- COLLADA /KML (SONY, Google)
- National 3D-4D-BIM Program (USGSA)
- 3DVIA (Bing Maps)

# Open Source Programming Libraries

- VTK
- Gorgon
- G3D Engine
- Cairo graphics
- OGRE
- OpenScene Graph
- Expression 3D
- libAfterimage
- Libart
- Interactive Visualization Framework
- Graphix
- Dislin
- MESA
- LibXML
- SciTech MGL
- ImageMagick
- LibWMF
- Paintlib
- PNG, TIFF, shape, JPEG
- gdLib

# 3D in Geobrowsers

- Picture and panorama inclusion
- Google streetview
- GoogleEarth 3D Buildings
- Bing Maps 3D and oblique views
- Microsoft Photosynth
- Most geobrowsers include topography

# Visualization

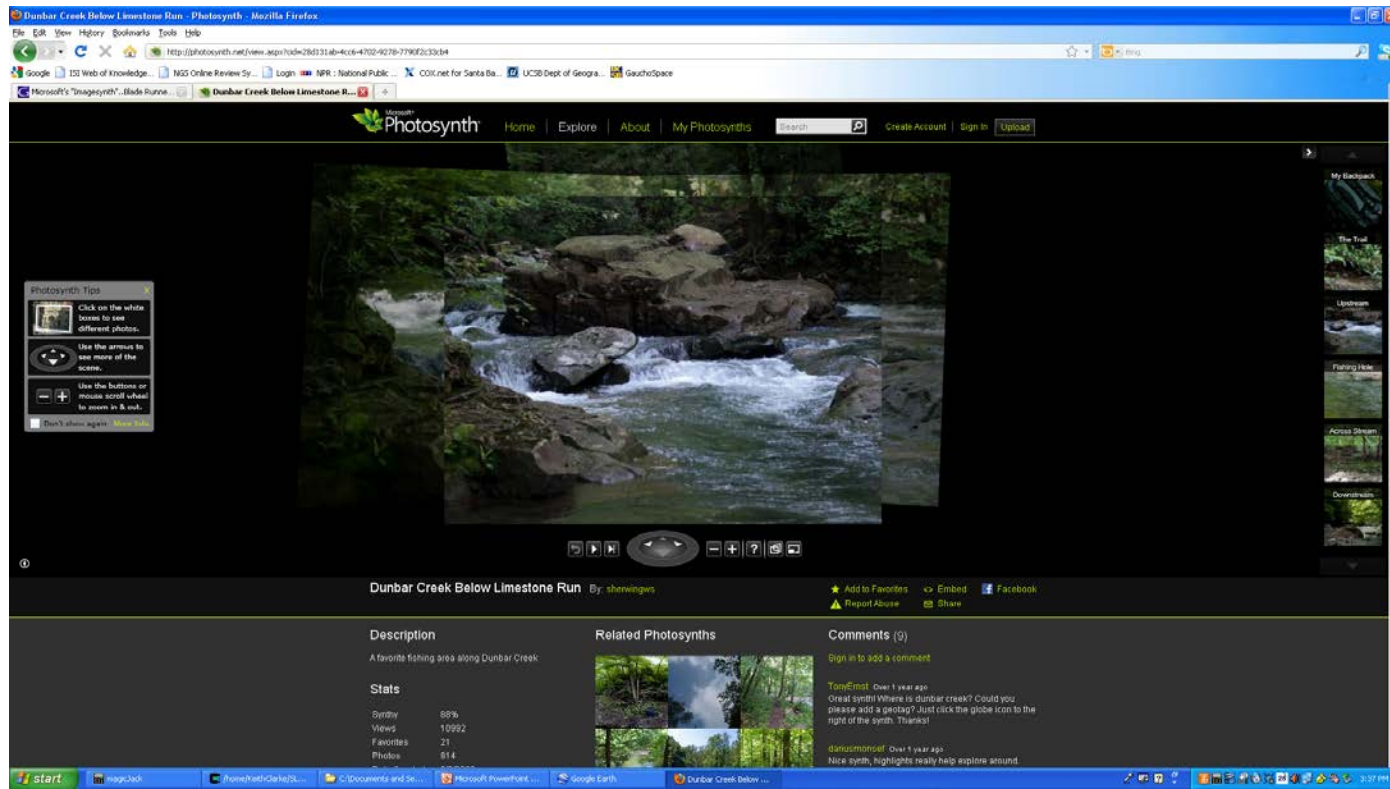
- Volunteered 3D information and multimedia: participatory sensing
- Visual Analytics
- Visualization of Uncertainty
- Spatialization

# Volunteered 3D information and multimedia

- Volunteered Geographic Information
- Use Contributed Content
- Examples: Google MyMaps, Flickr, Panoramio, YouTube, 4Square, Geocaching
- Can be institutionalized: e.g. National Map Corps.
- Data can be mined for content

# Microsoft Photosynth

- Use of multiple volunteered images to create camera viewing geometry
- Create zoom/pan view in great detail
- Others include PhotoFly (Autodesk) and bundler



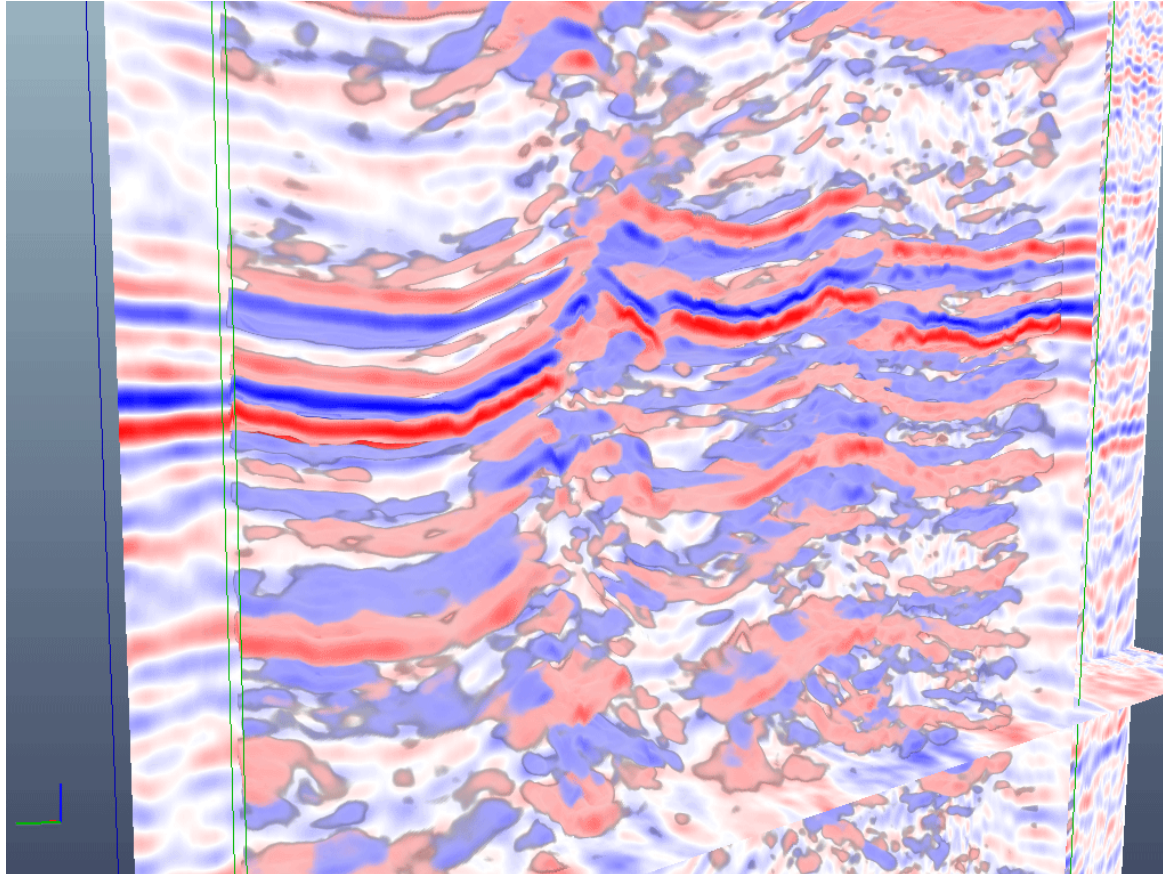
# Bundler

- Structure-from-motion system for unordered image collections (for instance, images from the Internet) written in C and C++. Opensource, UWash+Cornell
- Outdoor game: <http://photocitygame.com/>
- “Our ultimate goal is to reconstruct the entire world, one photo at a time.”





# Visualization of Uncertainty

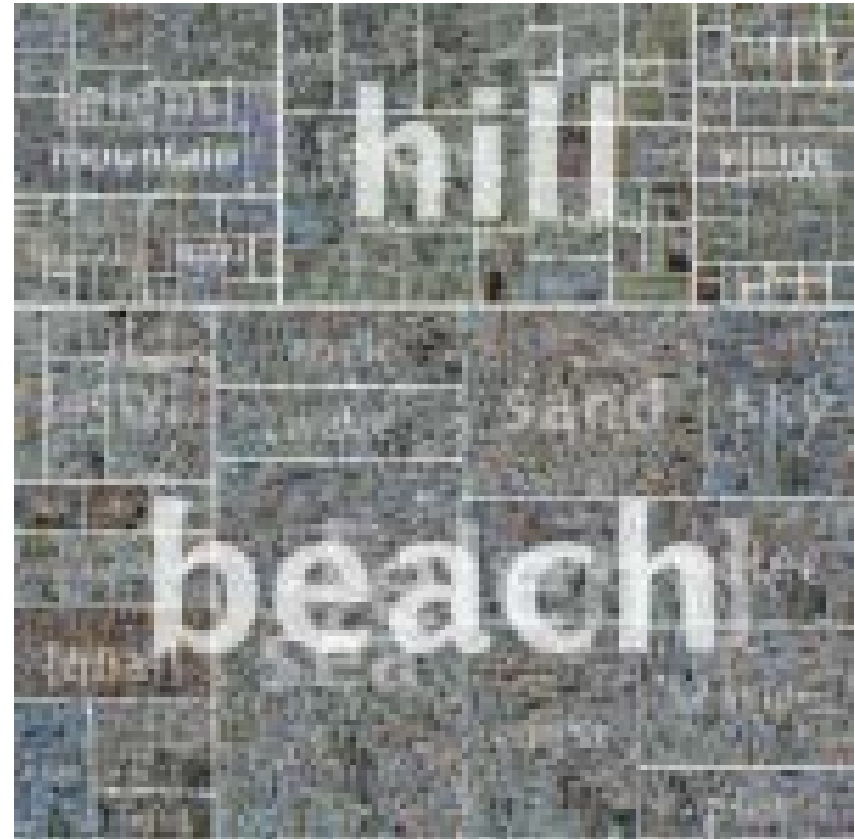
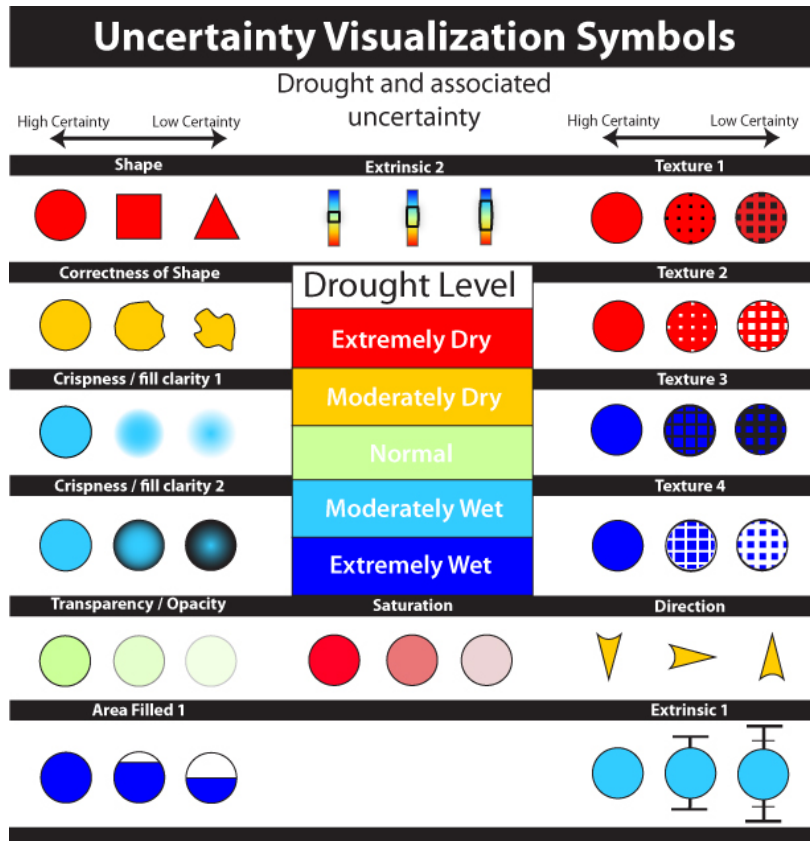


Prof. Dr. Bernd Fröhlich

**Visualization of Uncertainty: Visualizing Errors and Uncertainties in Geo-Scientific Data**

<http://www.uni-weimar.de/cms/medien/vr/research/visualization/scivis/uncvis.html>

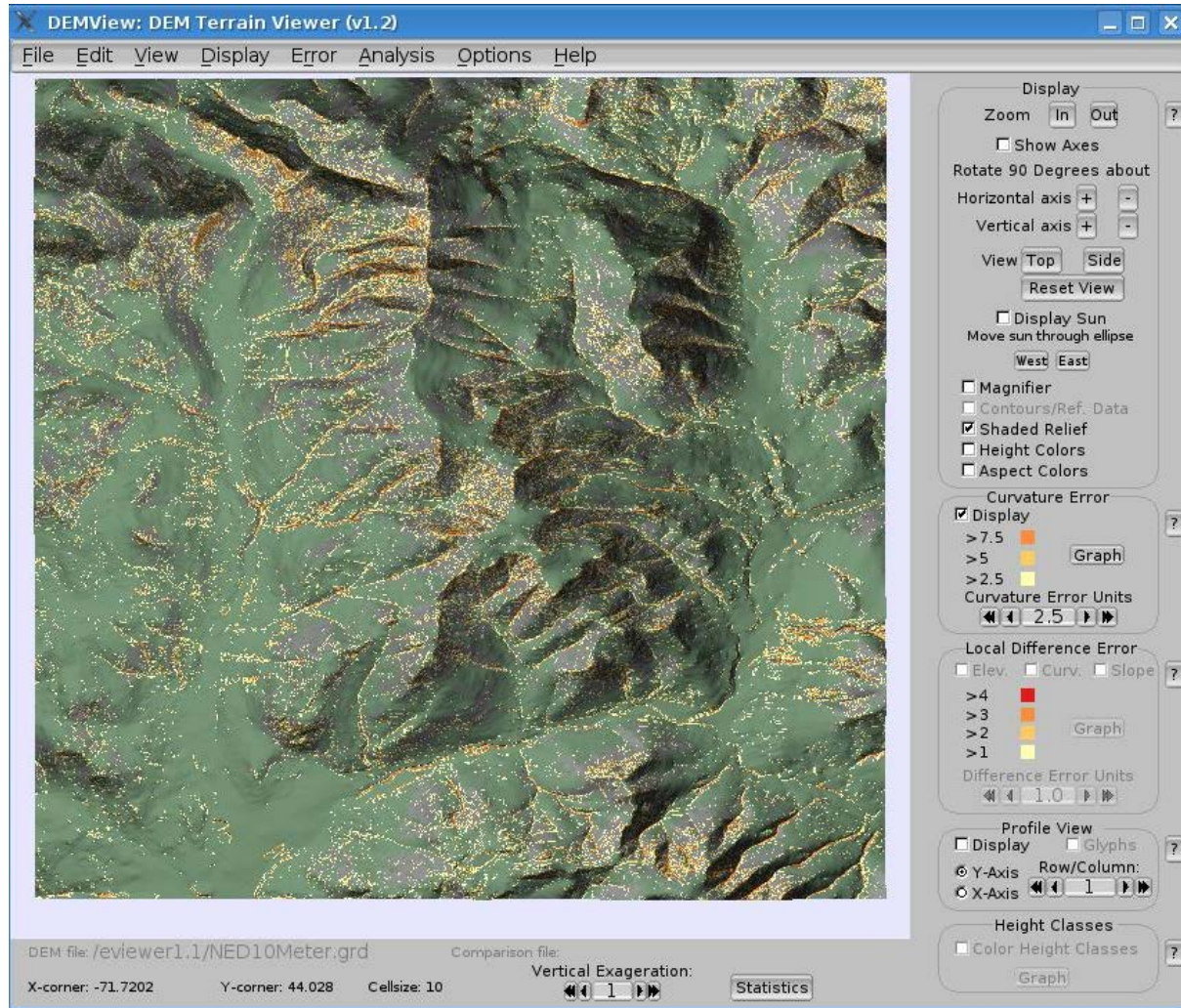
# Uncertainty issues



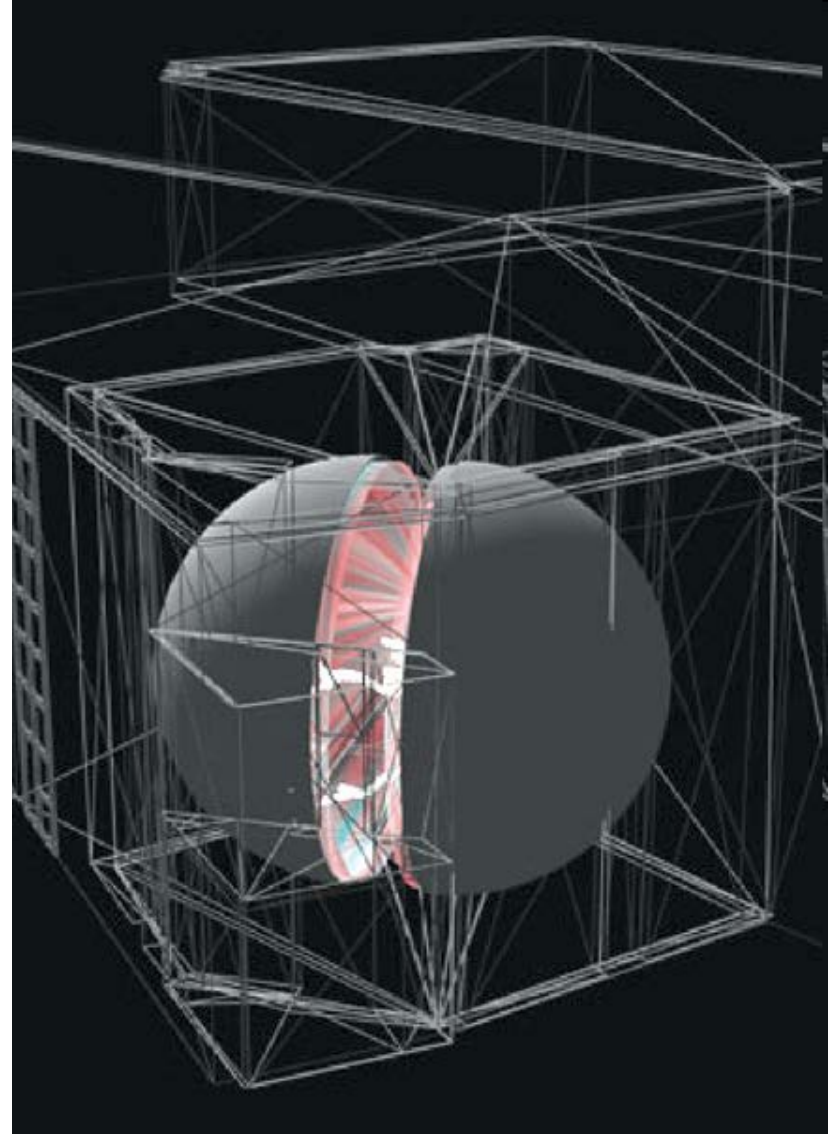
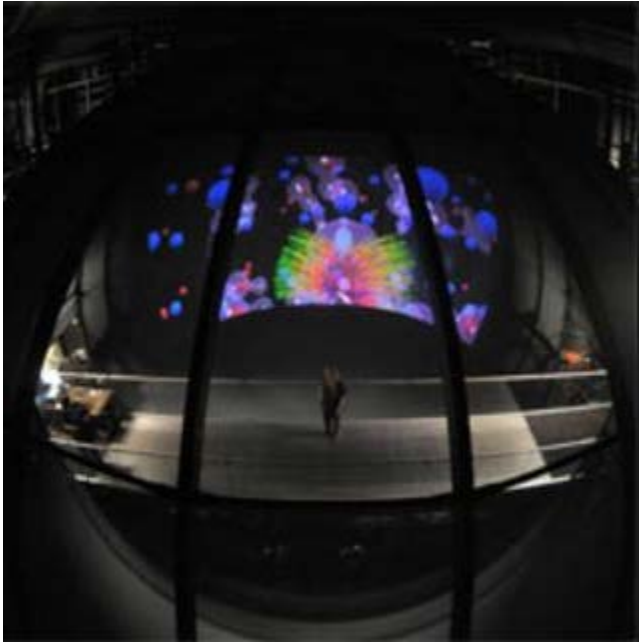
# Spatialization



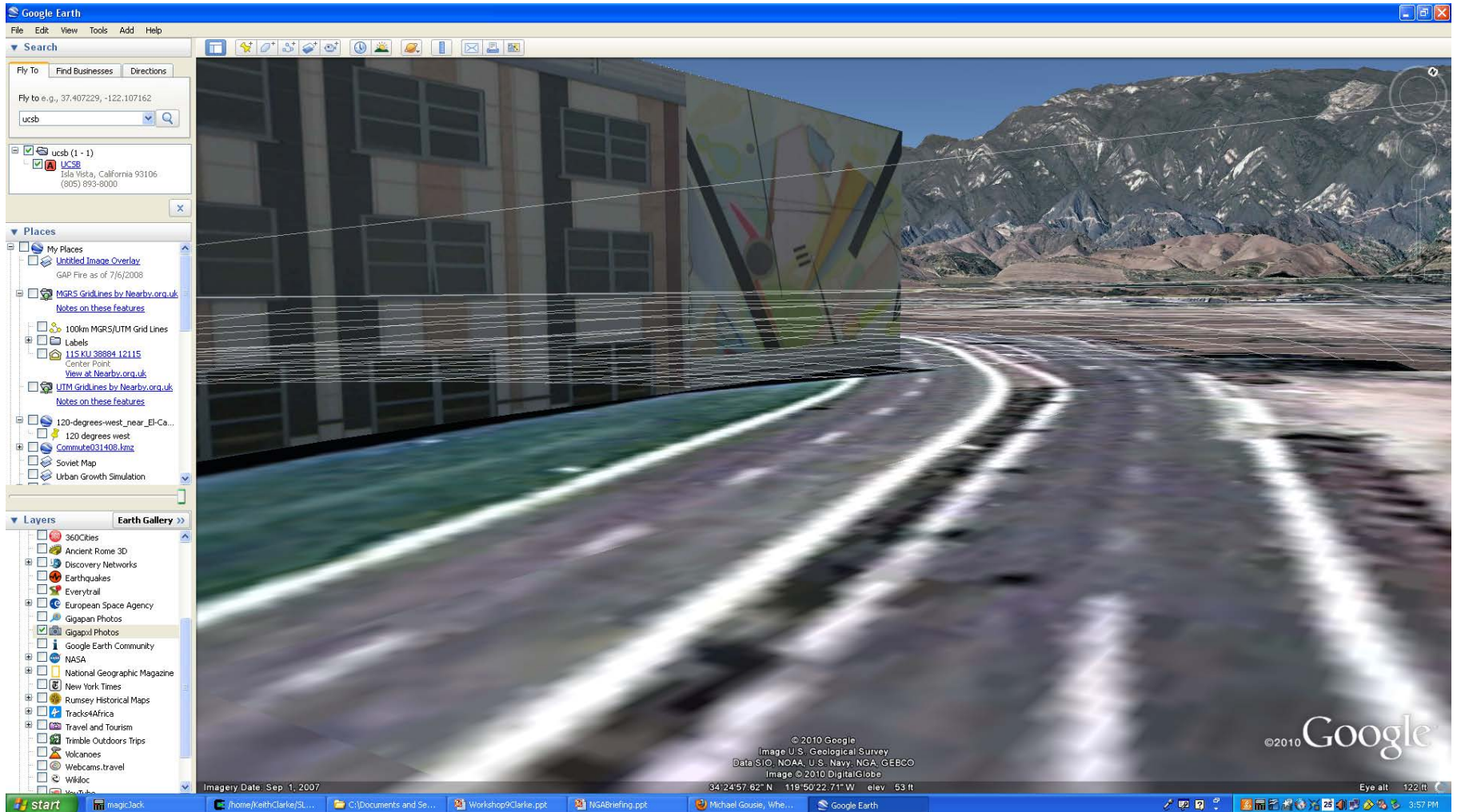
# DEMView



# Virtual Reality: The Allosphere



# A globe inside a globe?



# Mapping Interior Spaces

- Issue of coordinate systems
- Different accuracy needs
- GPS/GNSS does not work!
- What is an interior space?
- Can different methods be used in combination?
- NGA funded work under NURI: Jorge Chen

# Indoor Standards

## Highlighted Standards

- Industry Foundation Classes (IFC)
- City Geography Markup Language (CityGML)
- Indoor Geography Markup Language (IndoorGML)

## Other CAD Standards

- CIMsteel Integration Standards (CIS/2)
- Drawing Exchange Format (DXF)

## Other GIS Standards

- Shapefile
- Geodatabase
- Building Information Spatial Data Model (BISDM)
- Keyhole Markup Language (KML)

## CGI Modeling Standards

- Extensible 3D (X3D) and GeoVRML (predecessor)
- COLLABorative Design Activity (COLLADA)
- 3D PDF
- Minecraft Chunk



# CityGML Model of New York City by: DOITT Cadastre footprints + LiDAR

<https://tinyurl.com/glgzn7z>



# How to generate 3d model?

- Need many images from different angles
- Overlap creates stereo model
- Agisoft Photoscan then extracts model and assigns point cloud with color
- Can process with Meshlab, CloudCompare, other software
- Match with LiDAR and imagery data
- Our answer: LiDAR + Drone (Quadcopter)

# Phantom 4 with collision avoidance



Scans height by IR sensor

Position using GPS

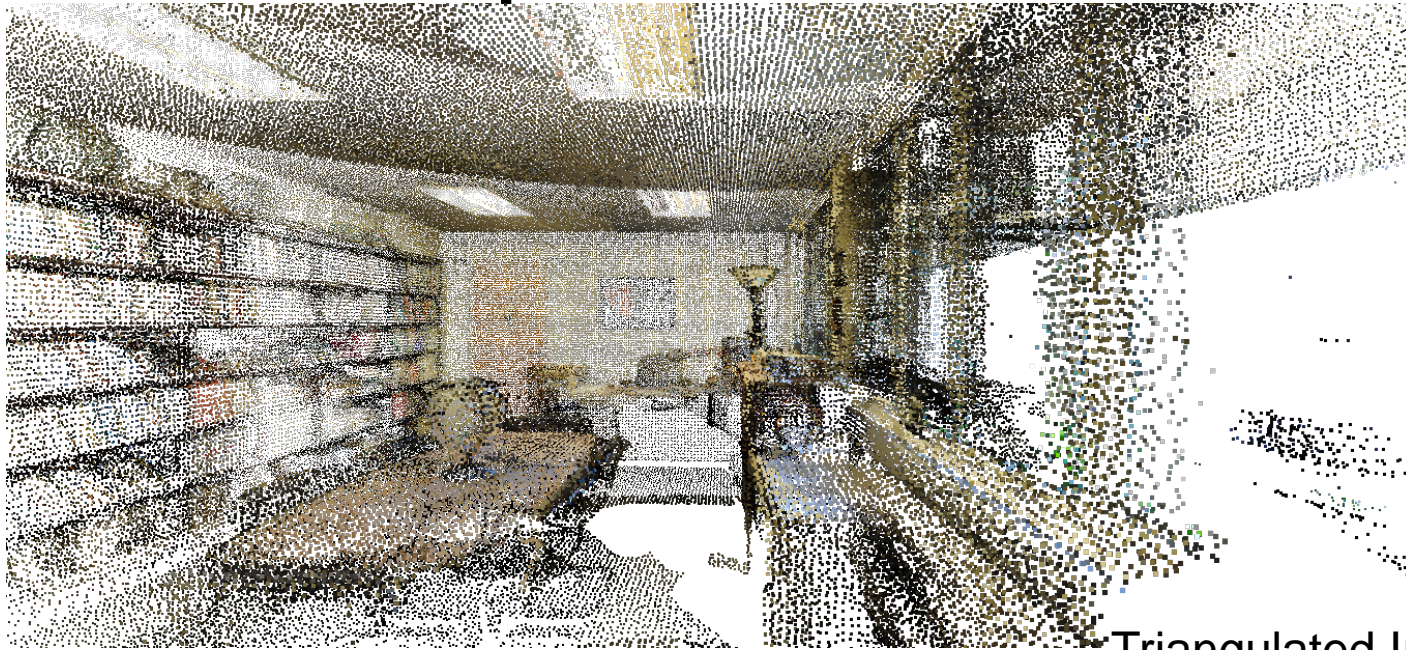
Fully gimballed camera

Can be programmed to collect  
video or interval images

20 minutes of flight with rechargeable batteries

Flight planning software, smartphone or tablet piloting

# Space abstraction



Point Cloud

Triangulated Irregular Network

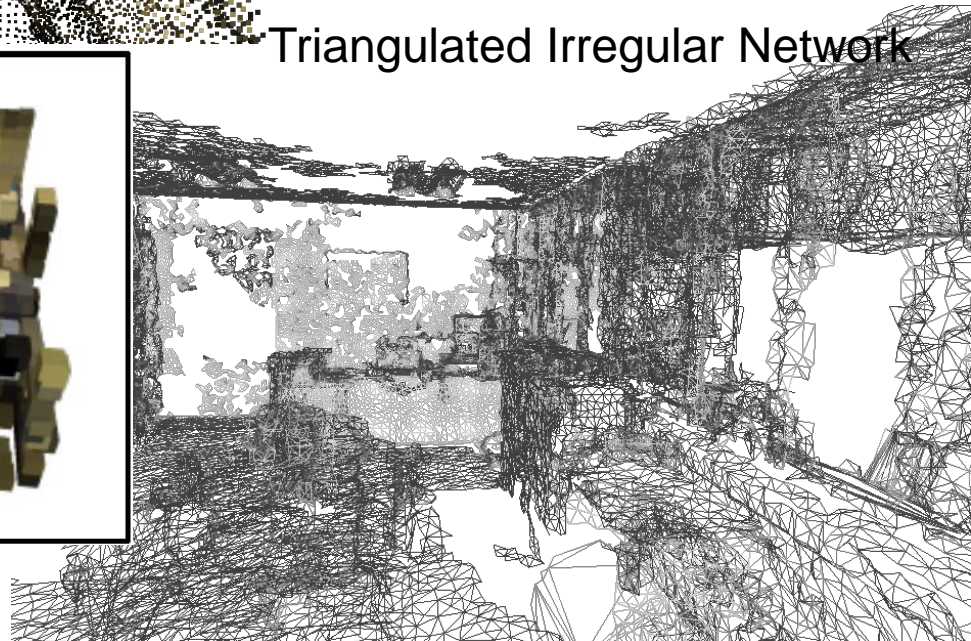


Voxel Size: 10 cm x 10 cm x 10 cm



Voxel Size: 25 cm x 25 cm x 25 cm

Voxels





# Proposed Methodology

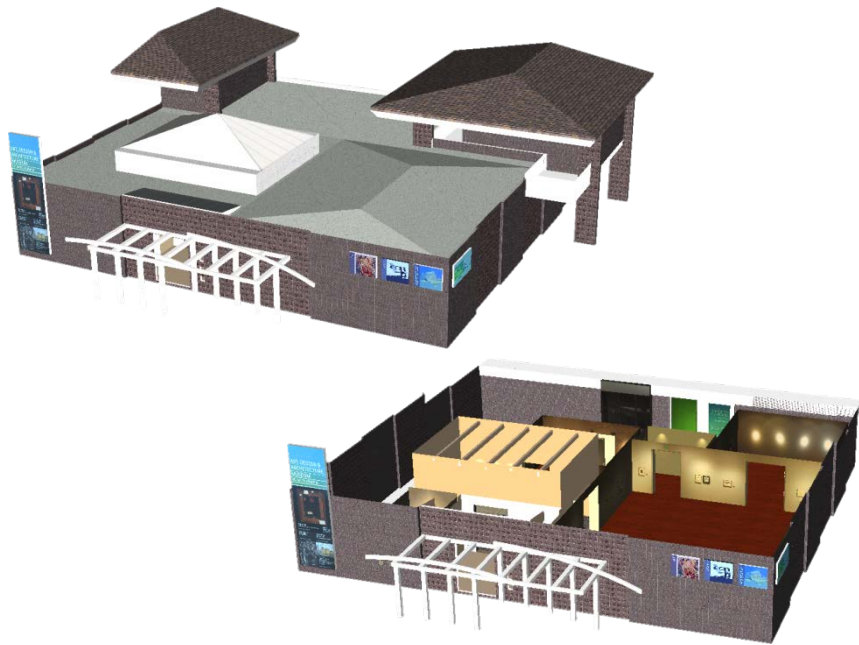
- Step 1: Global alignment (coarse alignment)
  - Get a “close enough” alignment for ICP
  - Three common tie points, distributed along the 3 axes
- Step 2: Variation of ICP algorithm (fine tuning)
  - Minimize the overall error in model fit

# Proposed Methodology

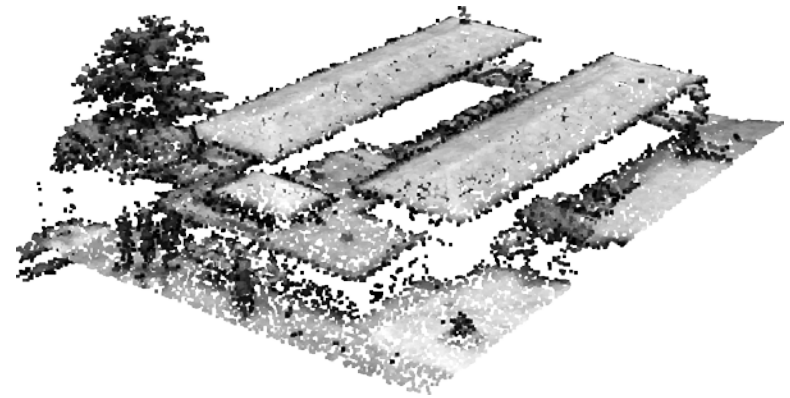
- Step 2: (Continued)
  - Constrain transformations to 2D rotations & translations
  - Iterate based on RMSE threshold or max. iterations
    - Minimize residuals between model-to-LiDAR points
    - Pivot/translate about geometric center of matched points
    - Progressively prune outliers as model and LiDAR converge
  - 1. Perform rotations until stable
    - x-axis => y-axis => z-axis, individually
  - 2. Perform translation
    - Simultaneous translation along all three axes
  - 3. Calculate RMSE
    - If  $RMSE > \text{threshold}$  (or)  $\text{iterations} < \text{max. iterations}$ , go to 1.
    - Or check for convergence

# Art Museum Case Study: Single Building

## Actual Data



Model  
local coordinates

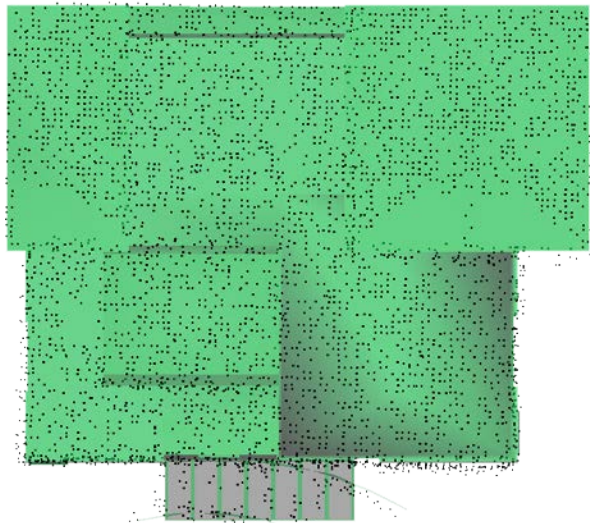


Aerial LiDAR Point Cloud  
geodetic coordinates  
(CA State Plane Zone 5)

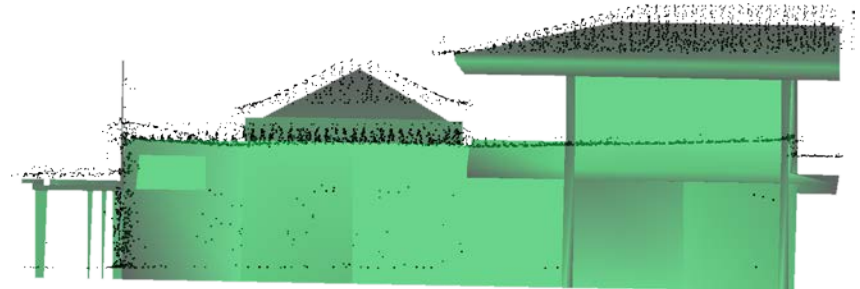
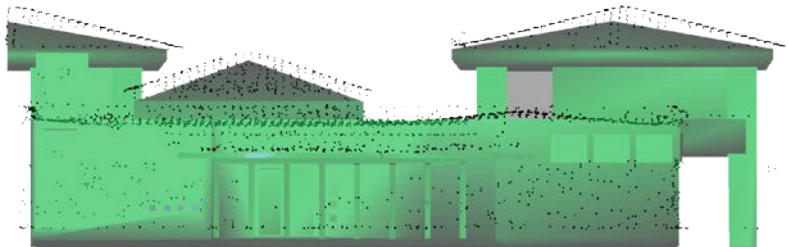
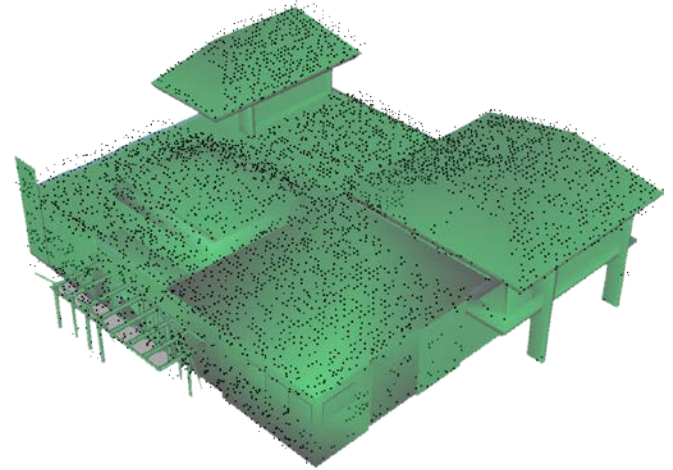


# Rough Global Alignment

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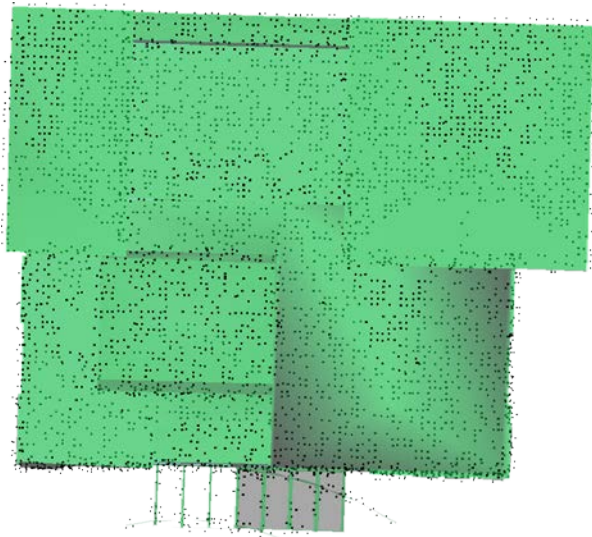


Est. RMSE  
Overall: 1.007  
m  
X: 0.640 m  
Y: 0.554 m  
Z: 0.544 m

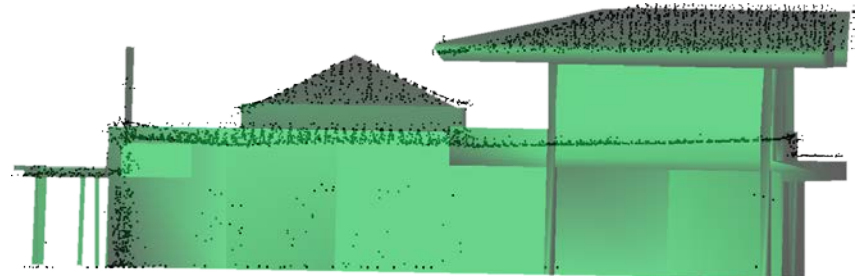
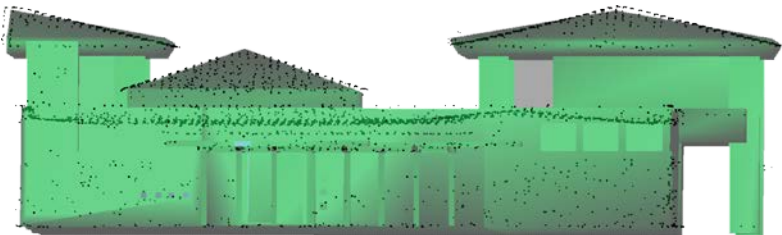
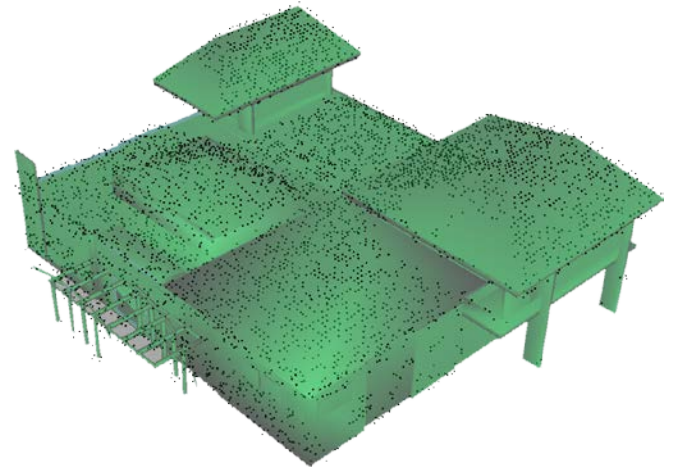


# Iteratively Refined Alignment

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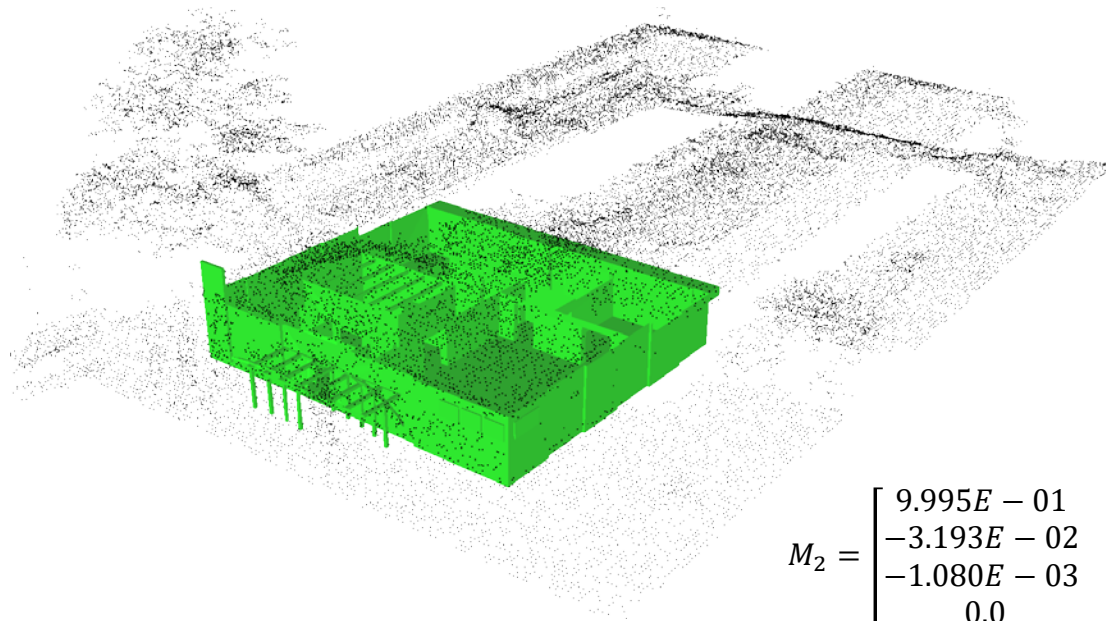
RMSE  
Overall: 0.132  
m  
X: 0.062 m  
Y: 0.059 m  
Z: 0.100 m



# Indoor Model in Geodetic Coordinates

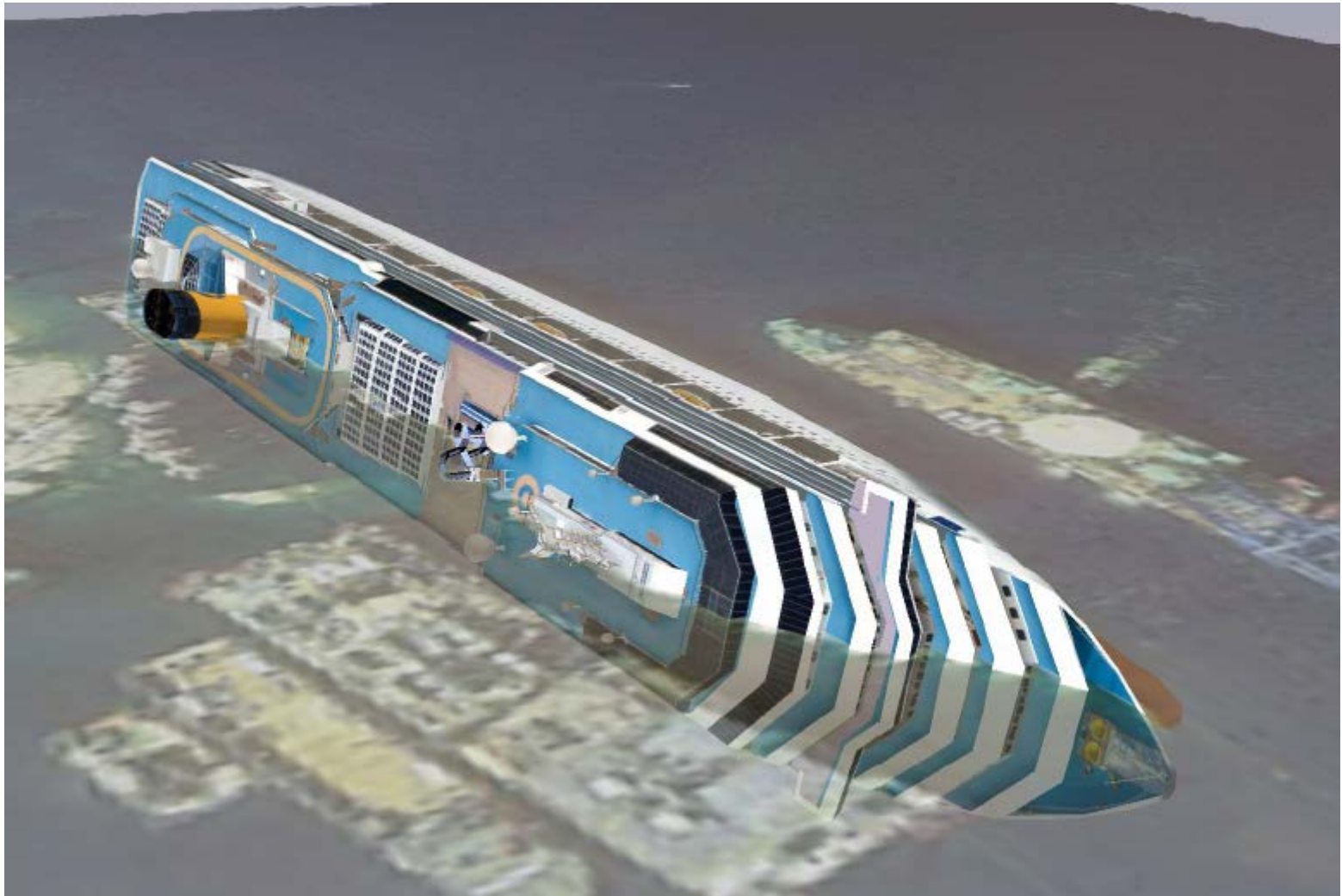
---

$$M_1 = \begin{bmatrix} 5.841E-07 & -9.998E-04 & -1.821E-05 & 1.831E+06 \\ 1.000E-03 & 5.973E-07 & -7.194E-07 & 6.022E+05 \\ 7.302E-07 & -1.820E-05 & 9.998E-04 & -7.865E+01 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}$$



$$M_2 = \begin{bmatrix} 9.995E-01 & 3.193E-02 & 1.163E-03 & -8.821E-01 \\ -3.193E-02 & 9.995E-01 & 2.607E-03 & 1.466E+00 \\ -1.080E-03 & -2.643E-03 & 1.000E+00 & 5.922E-01 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}$$

# Costa Concordia Case Study



# Summary

- Virtual globes—coming of age, new devices
- Exploits stereo vision
- Spectrum from augmented to immersive virtual
- Some new issues: visualization methods, LOD, uncertainty, etc
- Modeling issues, software and standards
- New mapping: interior spaces