Lecture 17: Cartography in virtual environments
Virtual reality: A spectrum

• **Virtual reality:** computer-simulated environment that can simulate physical presence in places in the real world or imagined worlds. Virtual reality can recreate sensory experiences, which include virtual taste, sight, smell, sound, and touch.
  - Immersive multimedia
  - Virtual environment

• **Mixed reality:** merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time.

• **Augmented reality:** a live direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data
Some history

• Mid 1950s, visionary cinematographer Morton H. Eilig built a single user console called Sensorama
  • stereoscopic display
  • fan scent 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.”
  • After using this display a person imagines the virtual world very similar to the real world.
  • During 1966, Sutherland built a tethered VR system
Sensorama and Headsight
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
Types of interaction

• Voice recognition
• Navigation
• Zoom: “Drill down”: Progression
• See through
• Search
• 3-D visualization and movement
• Time-line
• Multimedia : web links and portals
How does it work?

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

• A **virtual globe** is 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.
  • have the additional capability of representing many different views on the surface of the Earth
    • geographical features, man-made features such as roads and buildings, or 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*.
• The first widely publicized *online* virtual globes were NASA World Wind (released in mid-2004) and Google Earth (mid-2005)
• Many virtual globes exist today
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
- Baidu Map
- National Geographic Atlas
Augmented reality
Some issues

• How do you collect 3D data for photorealism?
• How much realism is necessary?
• How does interaction change the experience?
• What about permanent and temporary objects?
• How do you deal with underground and overlapping spaces?
• Cognitive disturbance: Foveation and peripheral vision altered
• Image lag and motion sickness
The issue: Can you sense reality?
Generalization in Computer Graphics: Level of Detail

#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: remote sensing of objects

- First generation DEMs, photogrammetry and contour conversion
- Second generation based on SAR and IFSAR
- SRTM near global coverage, 30m/90m
- GDEM global based on ASTER imagery
- NED completed at 30m, then 15m and less
- LIDAR has now taking over
- New photogrammetric methods showing promise
IFSAR DEM
\[ R = \text{Time delay}/2 \times \text{Light Vel.} \]
SRTM: Global topo map
How Lidar works
LIDAR first and last pulse
3D Models LiDAR
Terrestrial Scanning LiDAR
Lidar Point Cloud Data
UCSB Ellison Hall, 1st Floor

Primary Study Area
EH Room 1720

Secondary Study Area
EH Lobby

Additional Study Areas
North Wing Hallway
East Wing Hallway
East Stairwell

Data Collection Information
Platform: Riegl LMS-Z420i Laser Scanner
# Points: 35 million
Lidar Point Cloud Data
EH East Stairwell, 1st/2nd Floors
Platforms Tested To Date (EH Room 1720 Only)

- **Nikon D3100** (14.2 MP)
- **Microsoft LifeCam Studio** (2.1 MP)
- **Logitech QuickCam Deluxe** (0.3 MP)
- **Sony DSC-TX10** (16.2 MP)
- **Panasonic DMC-FZ28** (10.1 MP)
- **Riegl LMS-Z420i Laser Scanner** (Baseline Measurements)
Animated Point Cloud
(LifeCam Studio)
3D modeling and data structures

• Longley et. al. 6 models: gridded points, irregular points, cells, irregular polygons, TIN and contours
• Prior dominance of DEM
• Extensive use of TIN and surface patches
• Computer graphics and games favor Voxels
• LIDAR and photogrammetry return a POINT CLOUD
• Has led to use of term Digital Surface Model
Measurement vs. Modeling

• Select key surface points, edges
• Generalize remaining surfaces
• Solids modeling
• Feature extraction; Buildings, trees (e.g. Lidar analyst, Feature analyst, Quick Terrain modeler, TerraSolid (Microstation))
• Geometric vs. natural objects
• Realism vs. Size e.g. Google Object Warehouse
Point Clouds
BingMaps 3D Selected Cities (LA)
Simplest 3D tool: Sketch-Up (KML)
3D Buildings/Flat trees
Polygon extrusion (ArcScene)
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
- Softimage
- 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
• COLLADA /KML (SONY, Google)
• National 3D-4D-BIM Program (USGSA)
• 3DVIA (Bing Maps)
3D in Geobrowsers

• Picture and panorama inclusion
• Google streetview
• GoogleEarth 3D Buildings
• Bing Maps 3D and oblique views
• Microsoft Photosynth
• Most geobrowsers include topography
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/](http://photocitygame.com/)

• “Our ultimate goal is to reconstruct the entire world, one photo at a time.”
Virtual Reality: The Allosphere
Projected images
Augmented Reality
Kite photogrammetry

Figure 3. (a) Locations of 38 ground control points relative to mosaic’s extent. (b) Estimated camera positions for 357 images, superimposed on a map of image density.
3D Printing
Coordinate systems

Millimeter based
Uses 3 tie points
False origins with offsets
Can float with object
Implemented forward and inverse transforms
Space abstraction

Point Cloud

Triangulated Irregular Network

Voxels

Voxel Size: 10 cm x 10 cm x 10 cm

Voxel Size: 25 cm x 25 cm x 25 cm
Generalization
How to generate images?

- 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
- Our answer: Drone (Quadcopter)
Phantom 4 with collision avoidance

- Scans height by IR sensor
- Position using GPS
- Fully gimbaled camera
- Can be programmed to collect video or interval images
- 20 minutes of flight with rechargeable batteries
- Flight planning software, smartphone or tablet piloting
Mapping Ellison 1612
Image capture
Point Cloud
This is not a photograph
A 3D model from scratch
Closer to home
Summary

• Spectrum from augmented to virtual reality
• Term virtual environment useful
• Many cognitive and interaction issues for 3D
• Measurement technologies now ubiquitous
• LiDAR now moving to photogrammetry, DSMs and point clouds
• Applications in mapping and for LBS
• Many software systems and standards
• Expect more!