Goals for Today

- Why digitize?
- Example projects
- The Path to 3D
  - 3D digitization technologies available @ IU
    - 3D software modeling
    - Hardware-based 3D surface scanning
    - Software-based photogrammetry
    - Hardware-based volumetric
  - Post-processing workflows for all digitization technologies
- Recommended scanning and printing resources

Why Digitize?

- Digital preservation
- Artifact/Part analysis
- Metrology for reverse engineering, part inspection, redesign, and manufacture
- Reproduction through 3D printing

3D Digitization Example Projects

- Medical Related
  - CT/3D imaging with Tattiana Foroud, Ph.D.
  - Tissue Elasticity Ph.D. dissertation
- Personalized Radiation Therapy Data

Cultural Heritage

- Benjamin Harrison Presidential Site
- 18th c. Medical Libraries
- Dr. Leo J. Karpoff Collection
- Old Kitchen Bucket
Data Visualization Seminar:
3D Digitization
Jeff Rogers and Tassie Gniady

3D Digitization
Example Projects
• Analysis, Redesign, and Repurpose
  - Swim trainer reconstruction and redesign
  - Surgery training equipment enhancement
  - Engine part failure analysis
  - Defibrillator training app

3D Digitization
The Path to 3D

3D Digitization vs. 3D Modeling

3D Modeling Options
Measure and Model with Software Tools
• Lots of Software options
  – Polygonal modeling/Sculpting: Maya, Houdini, Blender, MudBox, ZBrush, ...
  – Parametric Modeling: Inventor, Solidworks, Rhino3D, ...
• Requires skills with select modeling packages
• Example Project: Scope lens extension
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3D Digitization Options

<table>
<thead>
<tr>
<th>Surface Scanning</th>
<th>Photogrammetry</th>
<th>Volumetric Scanning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pros</td>
<td>Pros</td>
<td>Pros</td>
</tr>
<tr>
<td>• Greater spatial accuracy (frame)</td>
<td>• Affordable equipment</td>
<td>• Captures internal structures, very high-resolution (2mm)</td>
</tr>
<tr>
<td>• Less time on site</td>
<td>• Highly portable</td>
<td>• Captures thin sections</td>
</tr>
<tr>
<td>• Immediate feedback on quality</td>
<td>• Underwater and aerial (drone) compatible</td>
<td>• Potential for user-friendly interface</td>
</tr>
<tr>
<td>• Less chance of user error/bad scale</td>
<td>• Real-time feedback for greater accuracy</td>
<td>• Potential for user-friendly interface</td>
</tr>
<tr>
<td>Cons</td>
<td>Cons</td>
<td>Cons</td>
</tr>
<tr>
<td>• Expensive equipment</td>
<td>• Lower spatial accuracy</td>
<td>• Captures thin sections</td>
</tr>
<tr>
<td>• Must upgrade equipment to achieve future gains</td>
<td>• Lengthy, computationally expensive</td>
<td>• Potential for user-friendly interface</td>
</tr>
<tr>
<td>• Lower resolution</td>
<td>• Required for use in thin bore wells</td>
<td>• Needs more processing time (getting faster)</td>
</tr>
<tr>
<td>• Challenges of processing in the field</td>
<td>• Potential for user-friendly interface</td>
<td>• Captures thin sections</td>
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<tr>
<td>• More time on site</td>
<td>• Captures thin sections</td>
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3D Digitization Options

Hardware-Based Surface Scanning

- Structured light scanners
- Laser time-of-flight scanners
- LIDAR

Photogrammetry Surface

- Use 2D images
- Structure-from-motion techniques

Hardware-Based Volumetric

- CT/MicronCT/CBCT
- Ultrasound
- MRI

Volumetric Scanning

- Captures internal structures, very high-resolution (2mm)
Hardware-Based 3D Scanning Setup

- Scanner Preparation
  - Calibration
  - Options
    - Color
    - Resolution
    - 3D mesh options
- Object Preparation
  - Surface preparation
  - Markers when needed
  - Dusting when needed
  - Foresee scan angles
  - Plan for merging scans

Hardware-Based 3D Scanning Scanning

- Scan
- Merge

Hardware-Based 3D Scanning Understanding the Limitations

- Accuracy: Certainty at the point of measurement
- Resolution: Distance between points of measurement
- Volumetric Accuracy: Certainty of point within unit of volume
- Example:
  - Go!Scan 5D: 0.1 mm accuracy
  - Resolution: 0.5 mm maximum
  - Volumetric accuracy: 0.3 mm/m

Hardware-Based 3D Scanning Understanding the Limitations

- Example: Elephant at 0.5, 1.0, and 2.0 mm resolution

Hardware-Based 3D Scanning Understanding the Limitations

- Go!Scan captures color, but not as well as Photogrammetry techniques
3D Digitization

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9/12/18

Hardware Based 3D Scanning
Understanding the Limitations

- Go!Scan captures color but not as well as photogrammetry techniques.

3D Digitization
The Path to 3D

3D Digitization
Photogrammetry System

- A method for extracting three-dimensional models or measurements of an object, environment, or terrain from a set of standard two-dimensional (2D) photographs.

- Applicable to a broad range of disciplines ranging from cultural heritage to archaeology to anthropology to medical science.

- Data collected from: smartphones, DSLR cameras, multi-camera rigs, spherical cameras, drones. May be merged with scanned meshes.

3D Digitization
Photogrammetry Workflow

- Lifecycle boost model
- Step 1: Capture the scene at multiple angles to help with camera calibration.

- Task Flow – Step 1

1. Align photos & generate point cloud
2. Build dense point cloud
3. Build mesh
4. Build texture

- Task Flow – Step 2

1. Align photos & generate point cloud
2. Build dense point cloud
3. Build mesh
4. Build texture

- Compute 3D coordinates of object points based on photo camera parameters.

- Usually largest share of computation time

- 3D Digitization
- Process Overview – Ernie Pyle Statue

- Life-size bronze statue (by Tuck Langland)
- 300+ photographs capturing all angles and details
texture-mapped 3D model (on Sketchfab)
### Task Flow – Step 3
1. Align photos & generate point cloud
2. Build dense point cloud
3. Build mesh
4. Build texture

### Task Flow – Step 4
1. Align photos & generate point cloud
2. Build dense point cloud
3. Build mesh
4. Build texture

### Benchmarking Dataset Stats

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Quality</th>
<th>Execution Time (sec)</th>
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<tbody>
<tr>
<td>Corn Maiden</td>
<td>medium</td>
<td>11 12 13 14 15</td>
</tr>
<tr>
<td></td>
<td>high</td>
<td>35 36 38 39 40</td>
</tr>
<tr>
<td>Ernie Pyle</td>
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<td>201 204 208 211 214</td>
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<tr>
<td></td>
<td>high</td>
<td>N/A 285 271 168</td>
</tr>
<tr>
<td>Monte Alban</td>
<td>medium</td>
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<td>N/A 576 580 580</td>
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### HPC Systems

<table>
<thead>
<tr>
<th>System</th>
<th>Node Type</th>
<th>CPU Type</th>
<th># Cores</th>
<th>RAM (GB)</th>
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<tbody>
<tr>
<td>Karst</td>
<td>IBM Maximo X360 M4</td>
<td>Intel Xeon E5-2650 v2 * 2</td>
<td>16</td>
<td>32</td>
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<tr>
<td>Big Red II</td>
<td>XE6</td>
<td>AMD Opteron 6276</td>
<td>32</td>
<td>64</td>
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<tr>
<td>Carbonate</td>
<td>Lenovo X399 M5 E5-2680 v3 * 2</td>
<td>Intel Xeon E5-2680 v3 * 2</td>
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### Execution Time

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### Speedup

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<tr>
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<tr>
<td>Big Red II</td>
<td>N/A</td>
</tr>
<tr>
<td>Carbonate</td>
<td>N/A</td>
</tr>
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</table>
Execution Time breakdown

Usage Data as of mid-July 2018
- # of jobs: 999
  - Many run by students
- Runtime in mins:
  - Mean: 140, median: 27, max: 1800, min: 1
- Requested # nodes:
  - Mean & median: 4, max: 30, min: 1
- # of photos:
  - Max: 14,261, min: 40

3D Digitization
The Path to 3D

3D Digitization
Volumetric Data Workflows

- Success Example: Prosthodontic Design
  - Combined Digitization
  - 3D Surface
  - Volume
  - Some photogrammetry
- 3D Printing
  - Positives for Quick Prototype
  - Negatives for Final Molds
- Interdepartmental Collaboration
  - Dentistry - Dr. Bellicchi
  - Informatics - Zeb Wood
  - IITS - AVL

- Success Example: Radiation Therapy Bolus
  - 3D Slicer & Plugin w/ AVL Workflow
  - Brian Owerlein: awarded a grant for new 3D print lab targeting medical applications with professional software and hardware.
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### 3D Digitization  
The Path to 3D

- **Target Applications**  
  - Digital preservation  
  - Web delivery and interactive apps  
  - 3D printing  
  - Redesign

- **Post-processing Techniques**  
  - Polygon decimation  
  - Color preservation  
  - Texture compression  
  - Parameterization

#### 3D Digitization  
Post-Processing

- **Example: Chunkey Stone Redesign**
  - Points and Polygons  
  - Sphere with Center and Radius

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### 3D Digitization  
Post-Processing

- **Target App: Web Delivery**
  - Post-processing techniques  
  - Polygon decimation: Reduce the number of polygons for faster web delivery  
  - Color preservation: Avoid color loss when polygon manipulation destroys color  
  - Texture compression: Save as JPEG

- **Example: Digital Preservation**
  - 1. Extract Parameters  
  - 2. Cross Section  
  - 3. Sketch  
  - 4. Mirror to Half Section  
  - 5. Revolve  
  - 6. Finished Part  
  - 7. Deviation Map

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### 3D Digitization  
Post-Processing

- **Target App: 3D Printing**
  - Post-processing techniques  
  - Polygon hole filling: Find and repair holes in the mesh, including removal of cross-facing polygons resulting in watertight mesh

- **Example: Chunkey Stone Redesign and Reproduce for Cultural Heritage Experience**
  - Sphere with Center and Radius

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### 3D Digitization  
Post-Processing

- **Target App: Redesign**
  - Post-processing techniques  
  - Parameterization: Extracting the parameters that mathematically define geometric objects  
  - Primitives: Spheres, Cylinders, Pyramids, Cubes, Cones, Planes  
  - Parametric equations for curves and surfaces

- **Example: Chunkey Stone Redesign**
  - Points and Polygons  
  - Sphere with Center and Radius
3D Digitization
The Path to 3D

Available Technologies
- 3D Surface scanning hardware
  - Creoform GoScan 2D for objects 0.5" to 2'
  - Creoform GoScan 50 for objects 4" to 17'
  - Makerbot scanners in 3D Print Labs
- Software: SolidWorks 2016 Workflows
  - Creoform VXElements (available for IU systems)
  - Geomagic DesignX (limited availability)
  - 3D Scan, 3D Scan Pro (available at IU)
- Meshmixer, Maya, Maelab, Blender, Mudbox, ...
- Free options like Meshlab, Blender, ...
- Zbrush
- Autodesk Meshmixer
- 3D Slicer
-...
Thank You!

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