Introduction

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Open Source 3D Scanning and Printing for Design Conceptualization and Realization

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PRESENTATION OVERVIEW

- Background
- Motivation
- Methodology
- Case Study
- Results
- Conclusions
- Future Work
Where do I pour my coffee?

• “I need a product that can hold hot liquid in the morning and that I can drink from (with one hand), while driving to work”
INDIVIDUAL NEEDS SCENARIOS

Individual knows how to communicate their need

3 Unknown Known

1 Known Known

Individual does not know their need

4 Unknown Unknown

2 Known Unknown

Individual does not know how to communicate their need

Motivation

http://www.engr.psu.edu/datalab/
INDIVIDUAL NEEDS SCENARIOS

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1 Known Known

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Motivation

http://www.engr.psu.edu/datalab/
Product Design and Development Process

- Identify Customer Needs
- Establish Target Specifications
- Generate Product Concepts
- Select Product Concept(s)
- Test Product Concept(s)
- Set Final Specifications
- Plan Downstream Development

Product Design and Development Process

Coffee Mug
Product Design and Development Process

Identify Customer Needs → Establish Target Specifications → Generate Product Concepts → Select Product Concept(s) → Test Product Concept(s) → Set Final Specifications → Plan Downstream Development
Product Design and Development Process

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Literature Review

http://www.engr.psu.edu/datalab/
What distinguishes YOU from an “expert designer”?

Individual

Knowledge
Technology

“Expert Designer”
INDIVIDUAL NEEDS SCENARIOS

Individual knows how to communicate their need

3
Unknown
Known

1
Known
Known

4
Unknown
Unknown

2
Known
Unknown

Individual does not know their need

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Research Hypothesis

Off-the-shelf scanning hardware and Open Source software enable design capture, reuse and realization with minimal loss of information.
History of Knowledge Democratization Via Technological Advancements

Then

Now

Research Hypothesis

• Speed/Efficiency
• Loss of Information
Methodology

1. Physical-Digital
   3D Scan

2. 3D CAD file

3. Open Source Network

4. 3D printing

5. Digital-Physical Prototype
Quantifying Information Propagation

**Complexity** = **Density**

\[ \text{Density}(V) = \frac{\text{numNbrs}(V)}{\sum_{i=1}^{\text{numNbrs}(V)} \text{edgeLength}(V, V_i)} \]

**Curvature**

\[ \text{Curvature}(V) = \frac{\text{numNbrs}(V)}{\sum_{i=1}^{\text{numNbrs}(V)} \text{cdiff}(N(V), N(V_i))} \]

- **numNbrs(V)** = Number of neighbors for vertex V
- **edgeLength(V, V_i)** = Edge length between vertex V and its adjacent vertices V_i
- **cdiff(x, y)** = cosine difference between normal vectors of vertex V and V_i (x and y are adjacent normal vectors represented by n_i, n_j and n_k)

Singh et al. (2011)
Open Source 3D scanning

• Off-the-shelf sensors are utilized to create 3D scans by taking multiple readings
Open Source 3D scanning

- 3D models are generated and exported as STL files
Design Restoration

• 3D point cloud data must be a manifold and free of errors

• The Open Source software, blender is used to repair errors
Prototyping

- The augmented design can then be digitally transmitted and shared
- 3D models are printed using low cost options such as RepRaps
Case study

- A off-the-self and relatively low cost depth sensor (30 Hz, 640 X 480, MS Kinect)
Case study

• The sensor was used to scan
  • i) a bottle of quick dry glue
  • ii) a white board eraser marker
  • iii) a coffee mug
Scan Schematic

24 INCHES

OBJECTS PLACED HERE

45 DEGREES

12 INCHES

OBJECTS PLACED HERE

24 INCHES
Dynamic 3D Generation

- Rotating the sensor around the objects created 3D scans
3D Design Augmentation

- Relevant parts selected and repaired
Physical Design Realization

• The mesh’s orientation and scale were checked before finally printing
## Results and Discussion

<table>
<thead>
<tr>
<th>Complexity Metric</th>
<th>Original 3D Scanned STL</th>
<th>Repaired 3D STL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>2.06</td>
<td>9.13</td>
</tr>
<tr>
<td>Curvature</td>
<td>0.019</td>
<td>0.026</td>
</tr>
<tr>
<td>Overall Complexity</td>
<td>1.013</td>
<td>1.059</td>
</tr>
</tbody>
</table>

![Original Object](Image1.png) ![3D Printed Object](Image2.png)
## Efficiency of Design Capture and Realization

<table>
<thead>
<tr>
<th></th>
<th>3D Scan</th>
<th>3D Repair</th>
<th>3D Print</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration</strong></td>
<td>5 minutes</td>
<td>60 minutes</td>
<td>120 minutes</td>
</tr>
<tr>
<td><strong>Expertise</strong></td>
<td>STL, KinectFusion</td>
<td>Manipulate a mesh in Blender)</td>
<td>G-Code, STL, RepRap</td>
</tr>
<tr>
<td><strong># Steps</strong></td>
<td>4</td>
<td>2 (clean, repair)</td>
<td>3 (orient, slice, print)</td>
</tr>
<tr>
<td><strong>Hardware Needed</strong></td>
<td>Kinect Sensor, PC</td>
<td>PC</td>
<td>PC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3D printer</td>
<td></td>
</tr>
<tr>
<td><strong>Software Needed</strong></td>
<td>Kinect SDK, KinectFusion code</td>
<td>Blender Netfabb (cloud service)</td>
<td>ReplicatorG</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Slic3r</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pronterface</td>
</tr>
</tbody>
</table>

Results

[http://www.engr.psu.edu/datalab/](http://www.engr.psu.edu/datalab/)
Where do I pour my coffee?

• “I need a product that can hold hot liquid in the morning and that I can drink from (with one hand), while driving to work”
Conclusion and Future Work

- Off-the-shelf scanning hardware and Open Source software enable design capture, reuse and realization with minimal loss of information

- Quantified the time and technology requirements of the design capture, reuse and realization process

- New data handling approaches and methods and reduction of error propagation
Acknowledgement & References

Contributors:
• D.A.T.A. Lab: Conrad S. Tucker, David St. John, Ishan Behoora, Alexandre Marcireau

References


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Questions