DETC2014-34801

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

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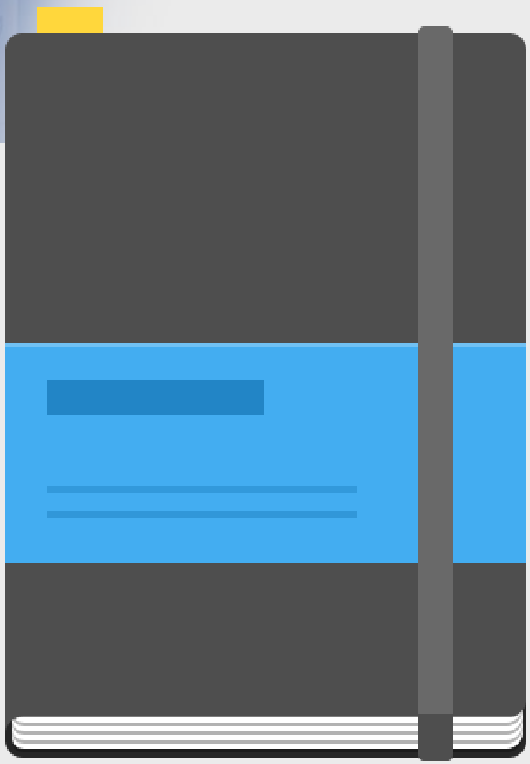
PRESENTATION OVERVIEW



- 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

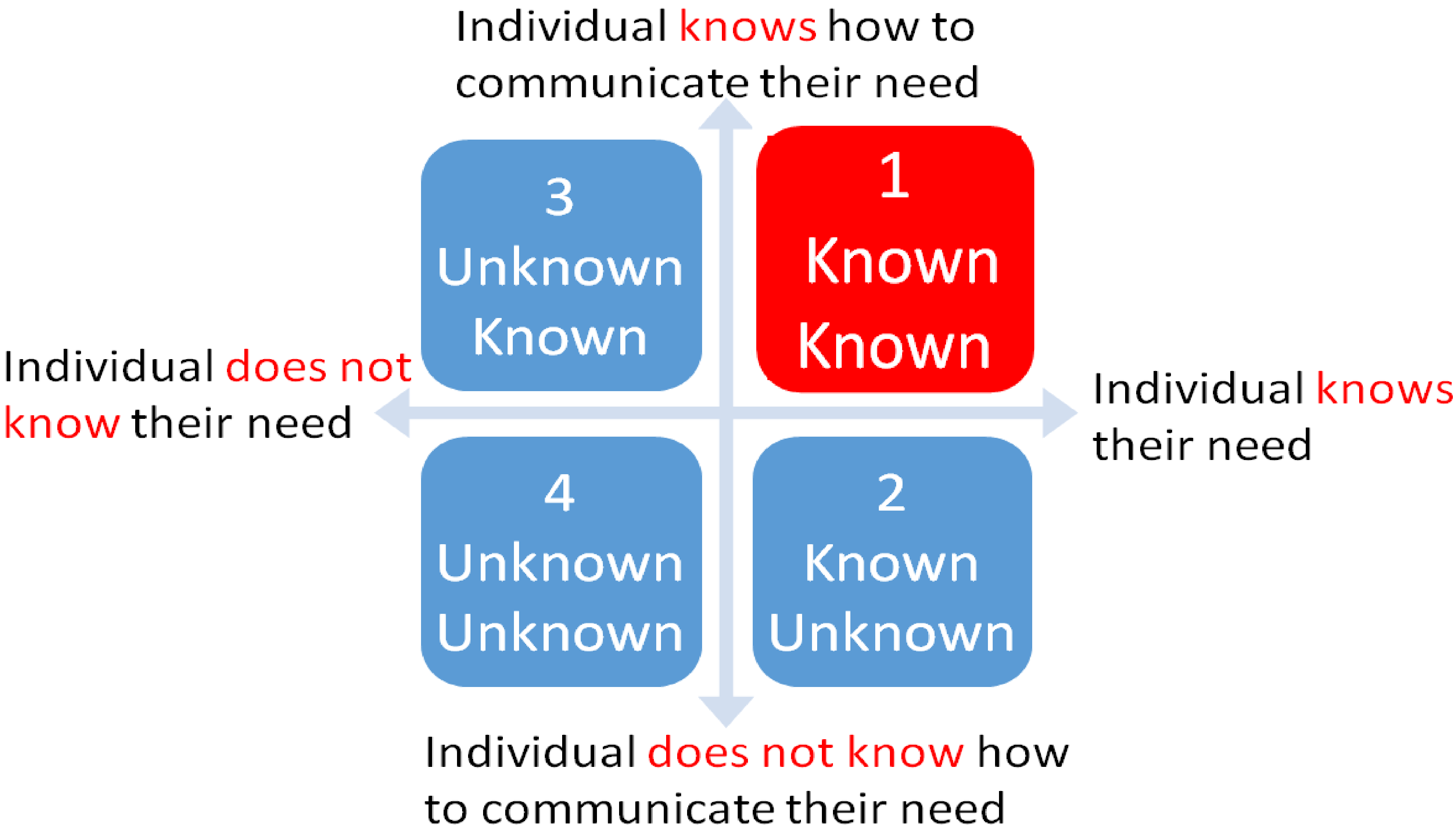
Individual knows their need

4
Unknown
Unknown

2
Known
Unknown

Individual does not know how to communicate their need

INDIVIDUAL NEEDS SCENARIOS



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

•Wassenaar, H.J. and W. Chen (2003); Michalek, *et al.* (2005); Lewis *et al.* (2006), Kumar *et al* (2007), Hoyle, C. and W. Chen (2009); Agard, B. and A. Kusiak (2004), Moon, *et al.* (2006), Simpson *et al.* (2014)

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Coffee Mug

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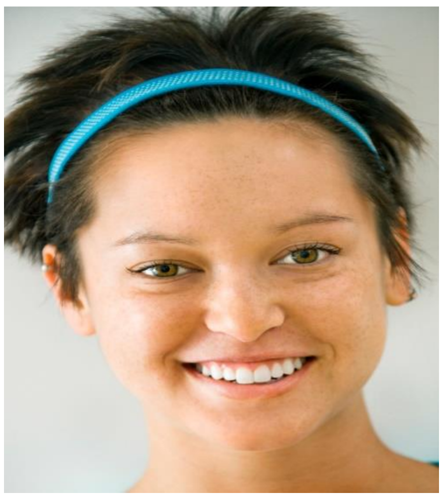
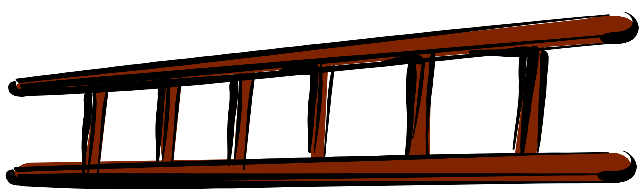
What distinguishes YOU from an "expert designer"?



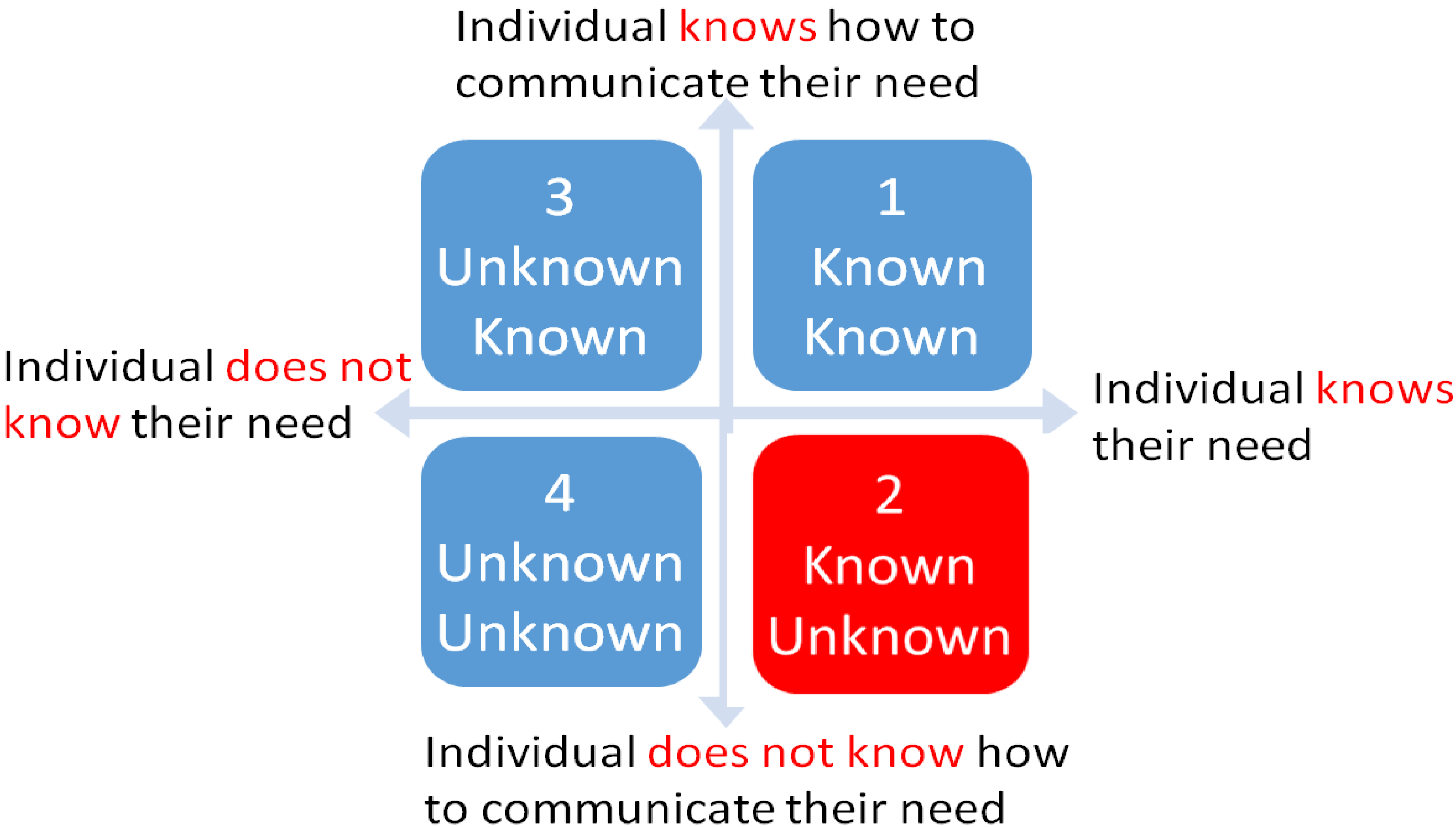
Knowledge
Technology



Individual

"Expert Designer"

INDIVIDUAL NEEDS SCENARIOS

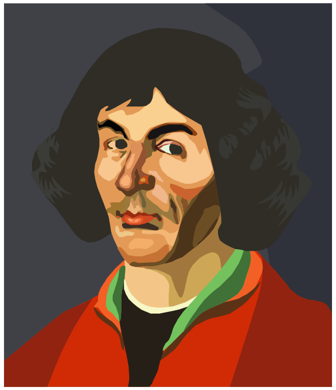


Research Hypothesis

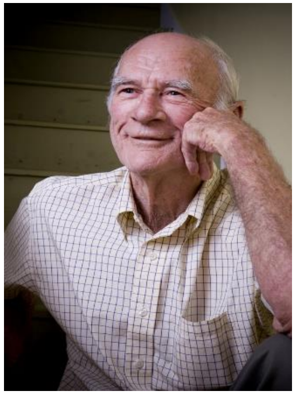
Off-the-shelf scanning hardware and Open Source software enable design capture, reuse and realization with <u>minimal</u> loss of information

History of Knowledge Democratization Via Technological Advancements

Then



Now

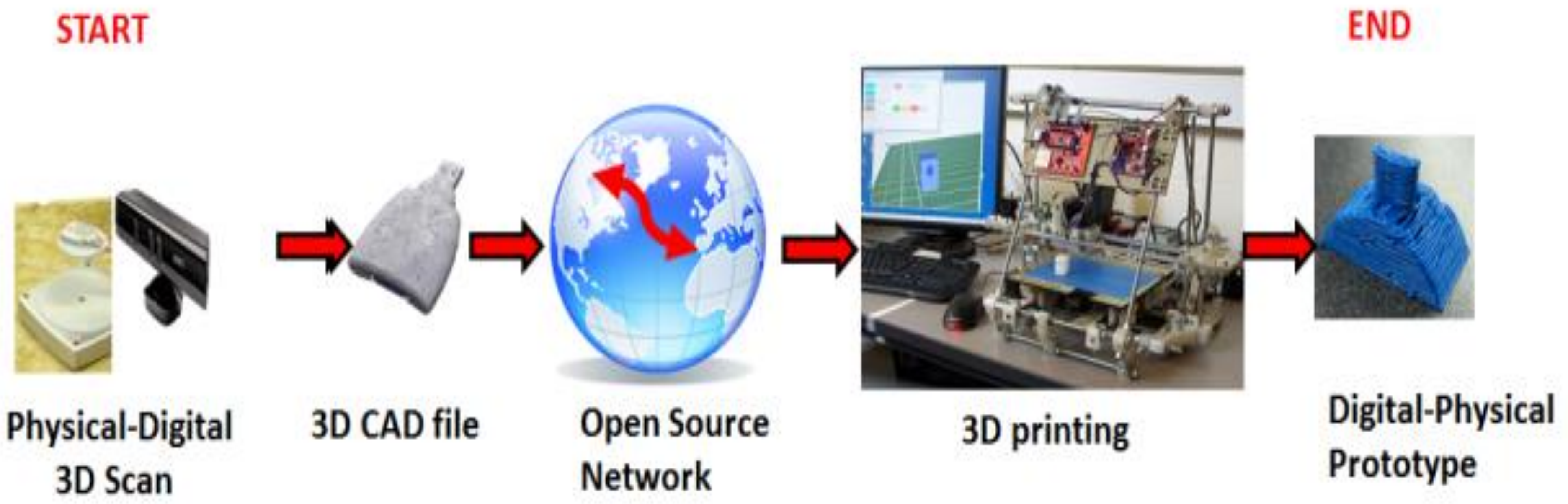


- Speed/Efficiency
- Loss of Information

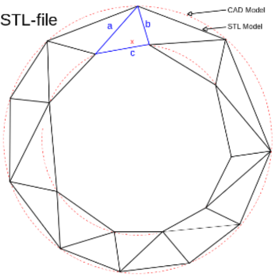
Then

Now

Methodology



Quantifying Information Propagation



$$Complexity = Density^{Curvature}$$

Singh et al. (2011)

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

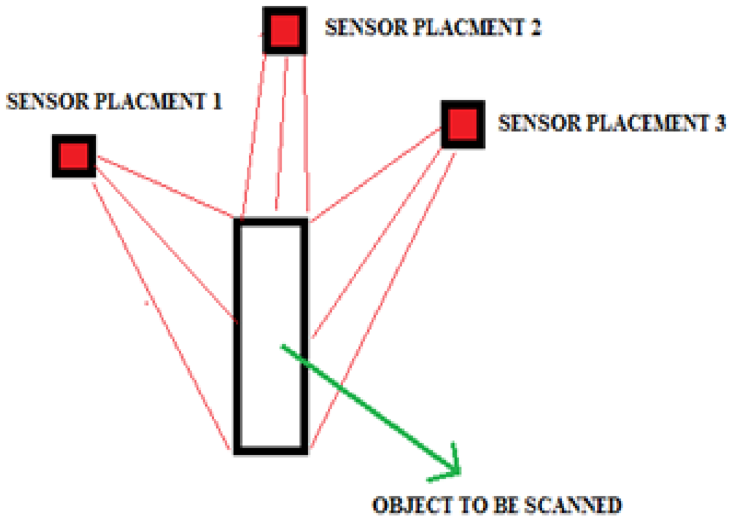
$$Curvature(V) = \sum_{i=1}^{numNbrs(V)} \frac{cdiff(N(V), N(Vi))}{numNbrs(V)}$$

- 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)

Open Source 3D scanning

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

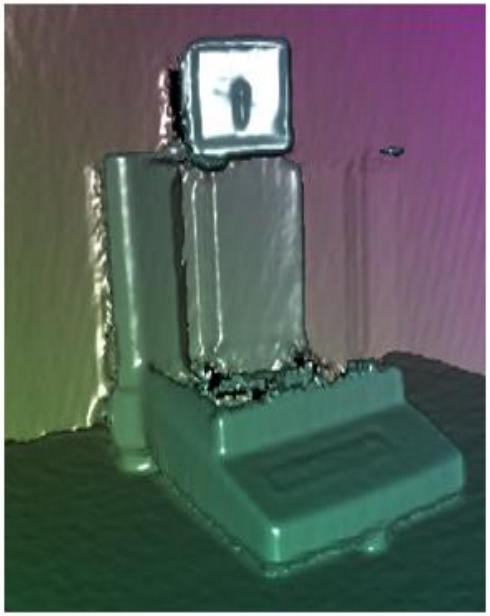


Open Source 3D scanning

- 3D models are generated and exported as STL files

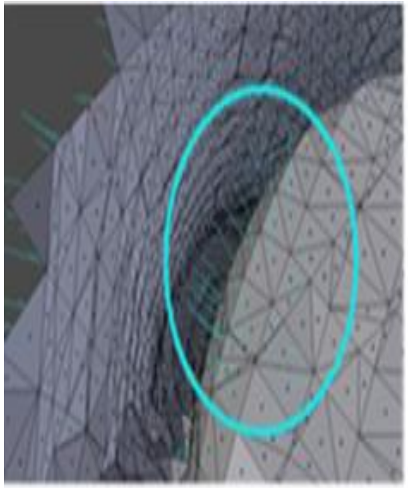
Visualization of Depth Readings

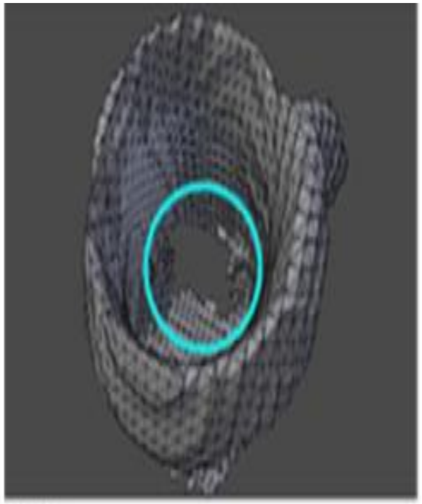
Resulting 3D Rendered Image

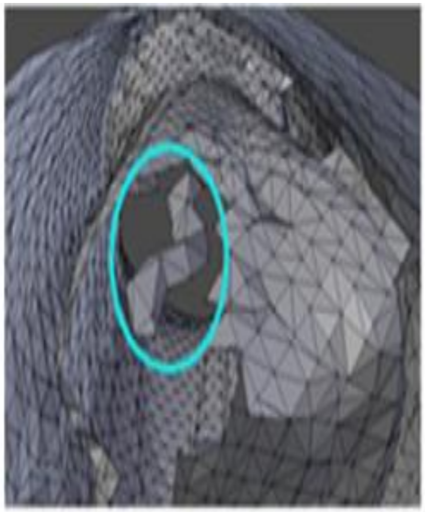


Design Restoration

- 3D point cloud data must be a manifold and free of errors
- The Open Source software, blender is used to repair errors

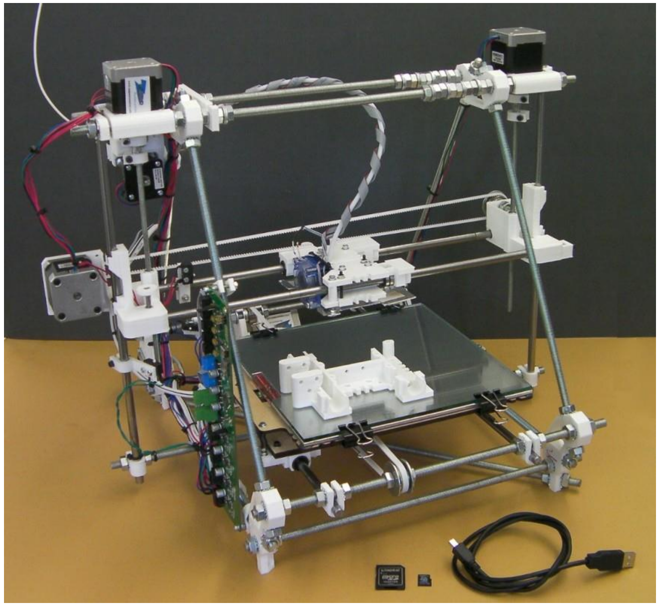

Inverted normals


Hole


Isolated faces

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)

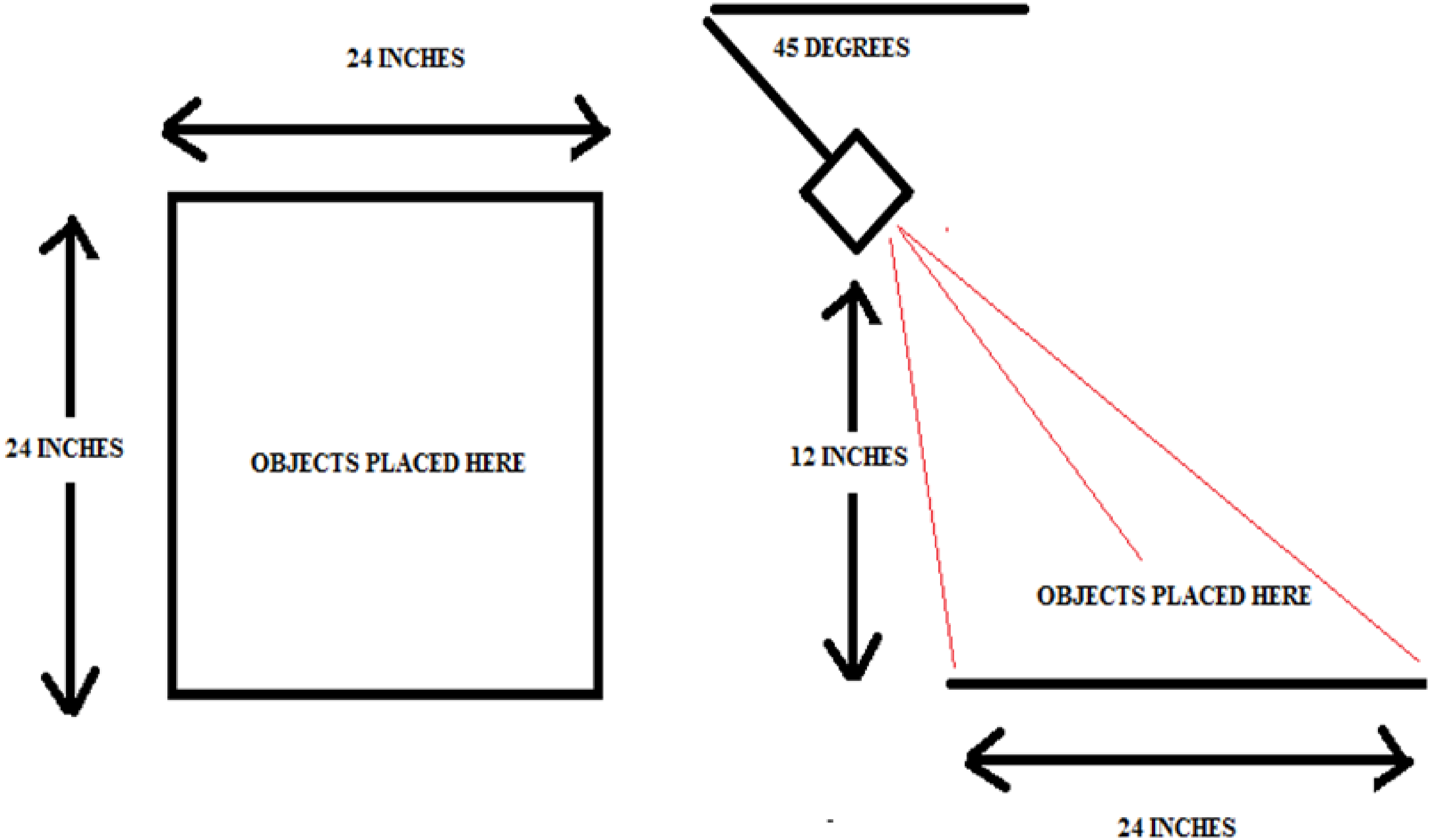
Kinect Multimodal Sensor

Real Time Depth Visualization

Case study

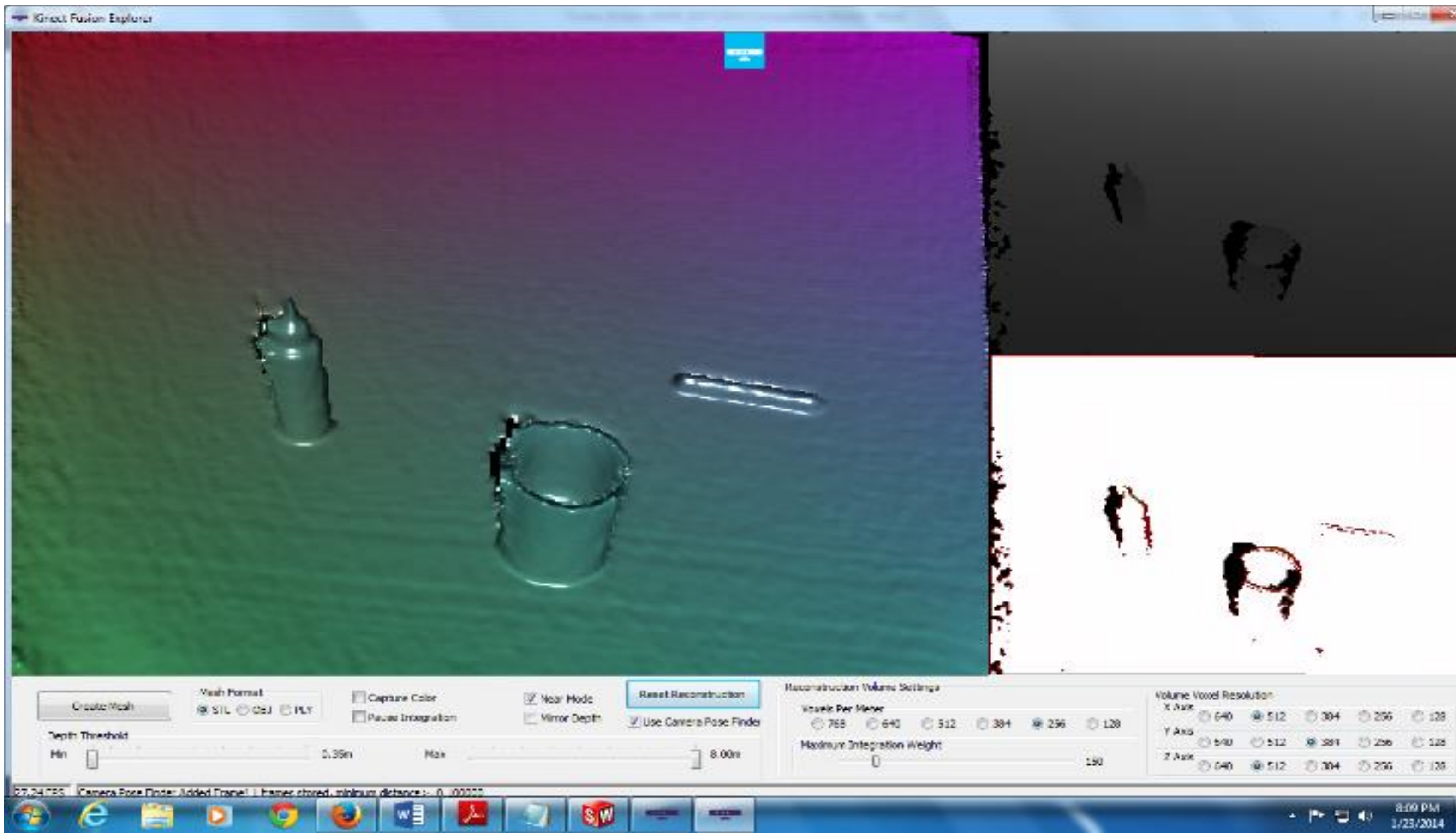
- The sensor was used to scan
- i) a bottle of quick dry glue
- ii) a white board eraser marker
- iii) a coffee mug

Scan Schematic



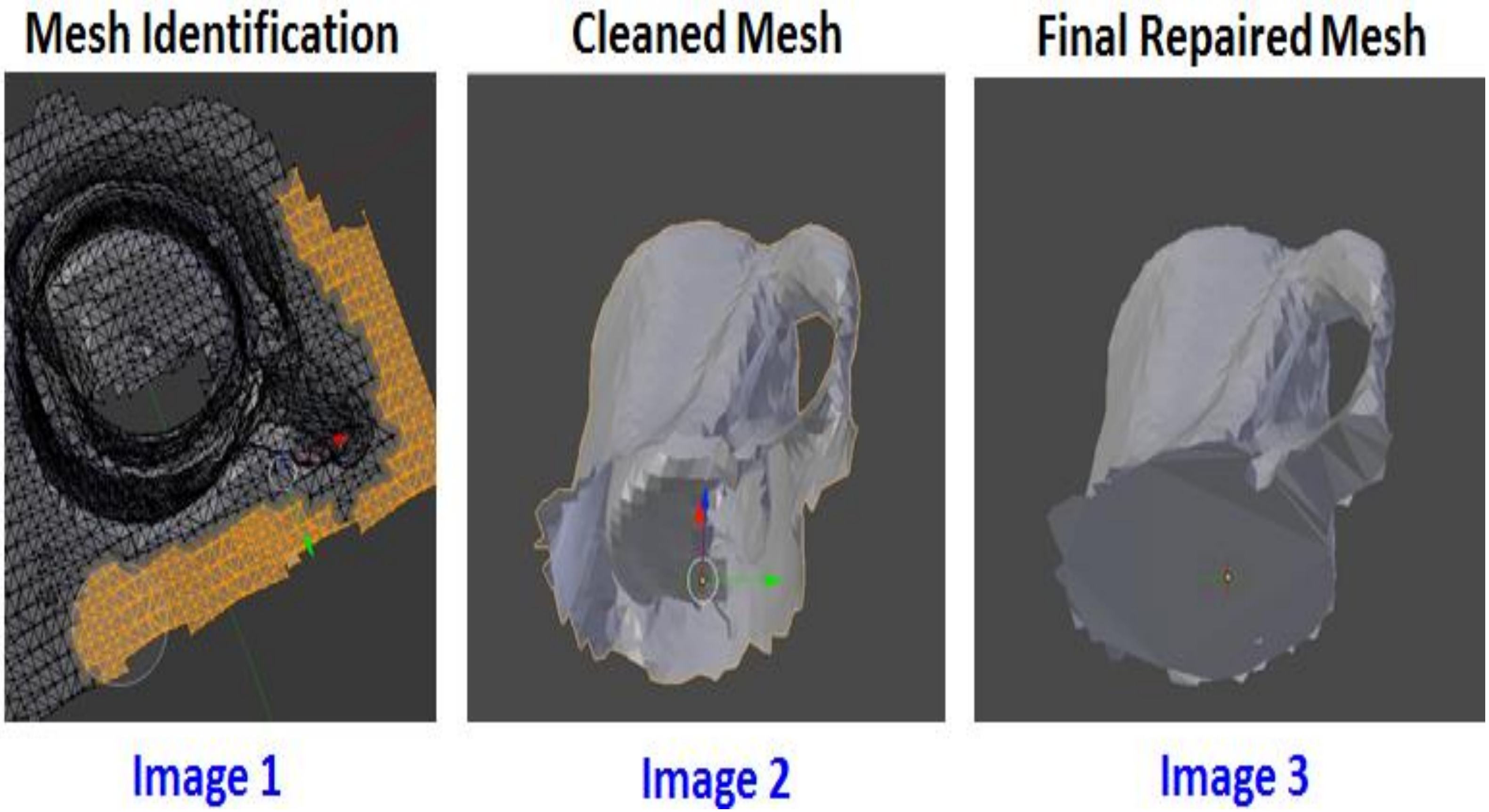
Dynamic 3D Generation

- Rotating the sensor around the objects created 3d scans



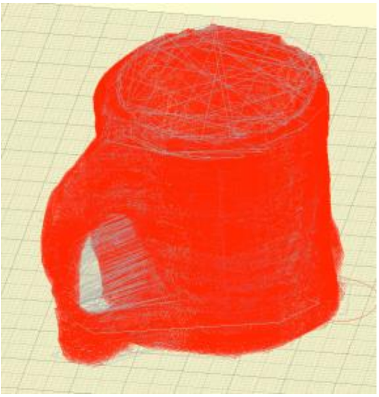
3D Design Augmentation

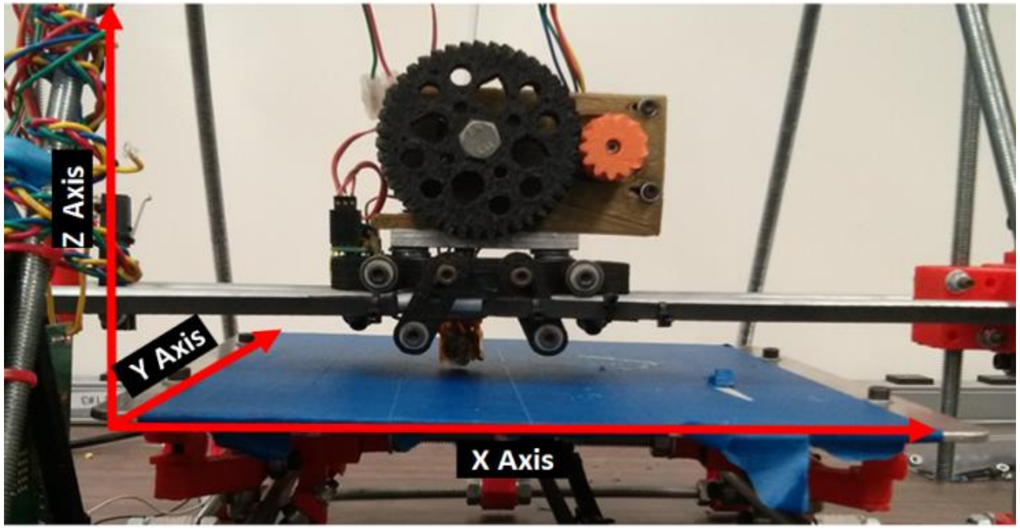
- Relevant parts selected and repaired



Physical Design Realization

- The mesh's orientation and scale were checked before finally printing





Results and Discussion

Complexity Metric	Original 3D Scanned STL	Repaired 3D STL
Density	2.06	9.13
Curvature	0.019	0.026
Overall Complexity	1.013	1.059

Original Object

3D Printed Object

Efficiency of Design Capture and Realization

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

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 <u>minimal</u> 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

[1] S. Rusinkiewicz, O. Hall-Holt, and M. Levoy, "Real-time 3D Model Acquisition," in *Proceedings of the 29th Annual Conference on Computer Graphics and Interactive Techniques*, New York, NY, USA, 2002, pp. 438–446.

[2] E. N. Wiebe, "Transfer of Learning Between 3D Modeling Systems," *EDGJ*, vol. 67, no. 3, Jun. 2009.

[3] H. M. Daanen and G. J. van de Water, "Whole body scanners," *Displays*, vol. 19, no. 3, pp. 111–120, Nov. 1998.

[4] "Professional 3D Printing | Stratasys." [Online]. Available: http://www.stratasys.com/. [Accessed: 25-Jan-2014].

Questions