


Computational Fabrication

Deep Learning for Advanced 3D Printing

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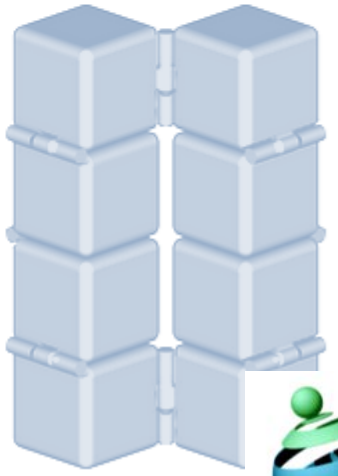
Director, Social Fabrication Laboratory, Keio University SFC
JST Center Of Innovation Program



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Applications of Additive Manufacturing

Nursing and Medical Care

Architecture

Fashion

Food

Metal Industry

Education

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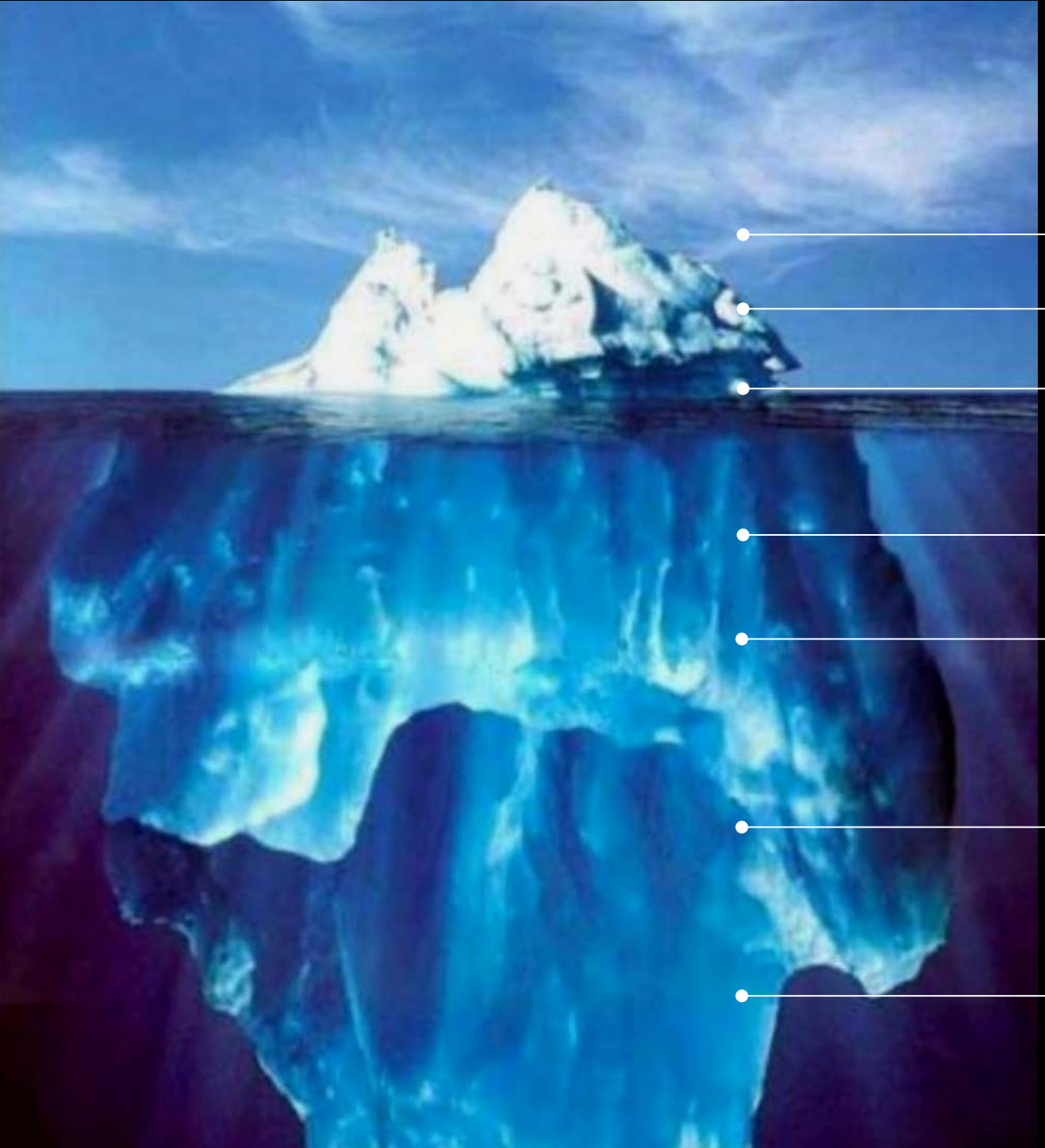

3D Printing as an Iceberg

- **Processes**
- **Materials**
- **Machines**

Physical

- **Data Format, Data Base**
  ISO/TC261 Data Format for additive manufacturing
- **3D Object Retrieval,**
  3D Object Generation
- **CAD-CAM-CAE-CAT**
  Workflow, FeedBack

Virtual

- **Machine Learning**

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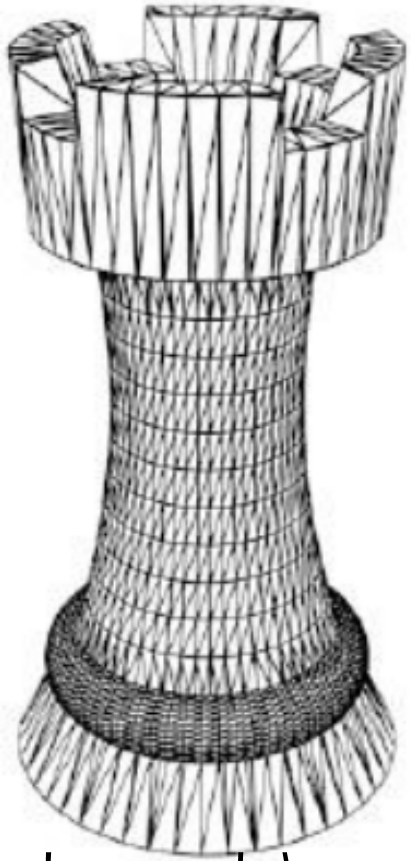
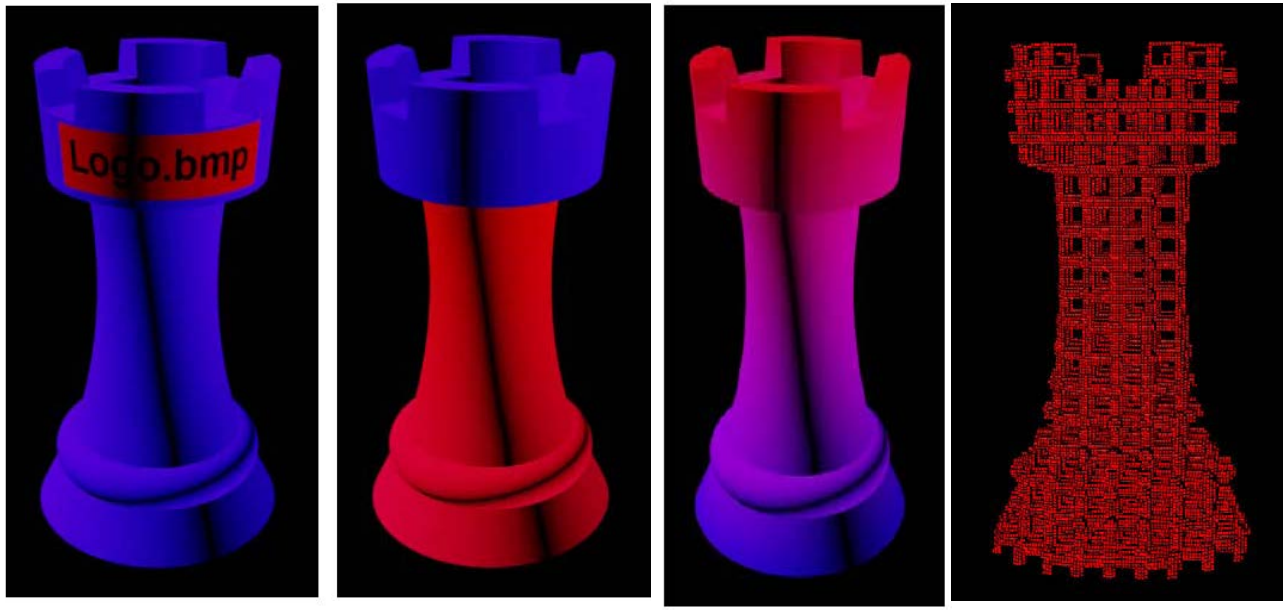
3D Printing File Format



STL (only mesh)

"STereoLithography"
"Standard Triangle Language"
"Standard Tessellation Language



Texture Color Material Grading Microstructure

AMF (Additive Manufacturing File Format)
ISO/ASTM 52915, 2013

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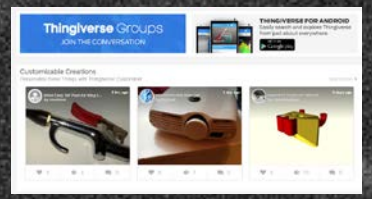
3D Data Sharing Portals

Public Sectors

Thingiverse



sketchfab

1200000

Smithonian Museum 3D

NASA

NIH

Cross-Search Engine: Fab3D
(Keio University)

3D Data (STL) on the Internet

Retails

Dentals

Metal Parts Provider

Schools

Personal Site

Companies

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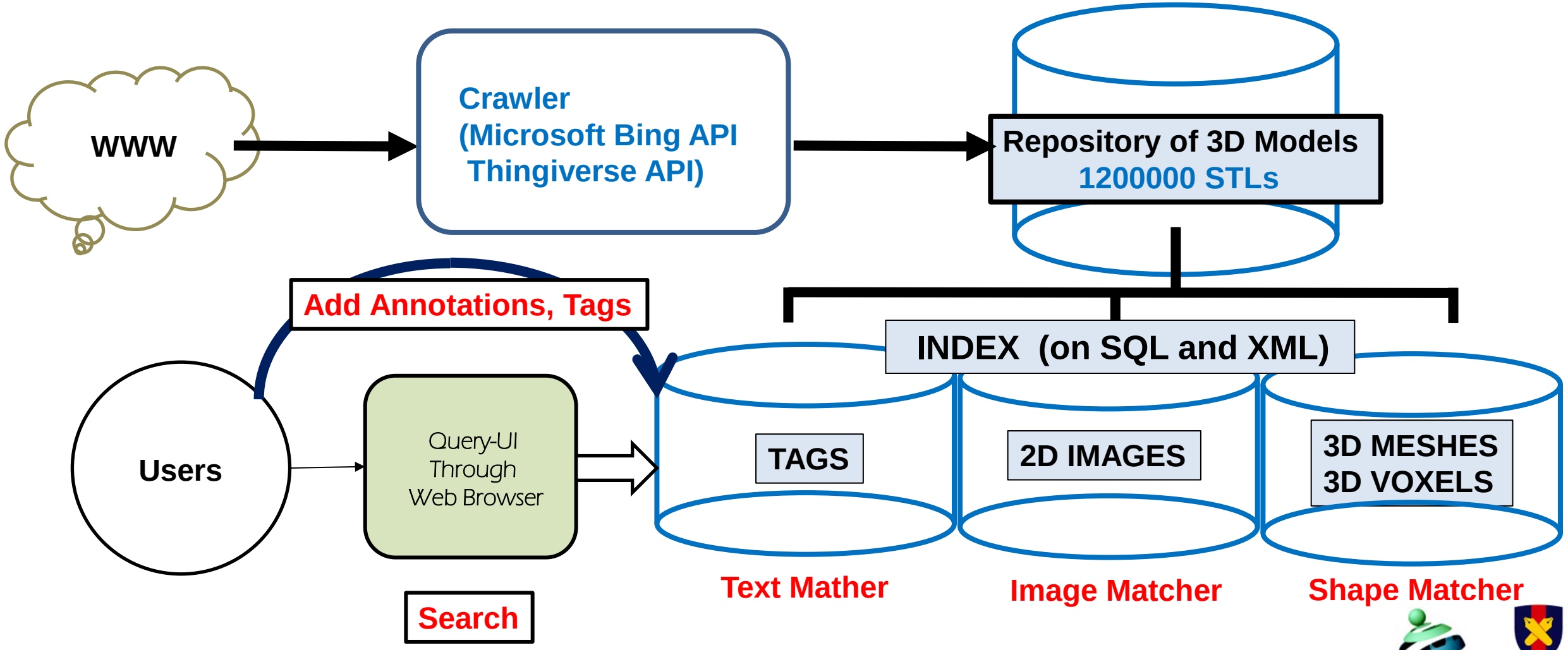
3D Search Engine : System Overview



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Cross-Search Engine: Fab3d (http://fab3d.cc)

Front_motor_mount_DJI_2212.stl
http://www.thingiverse.com/thing:713099
License: CC BY-SA Size: 877K
Edit & Save

Tail_motor_mount.stl
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License: CC BY-SA Size: 655K
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Motor_igen.stl
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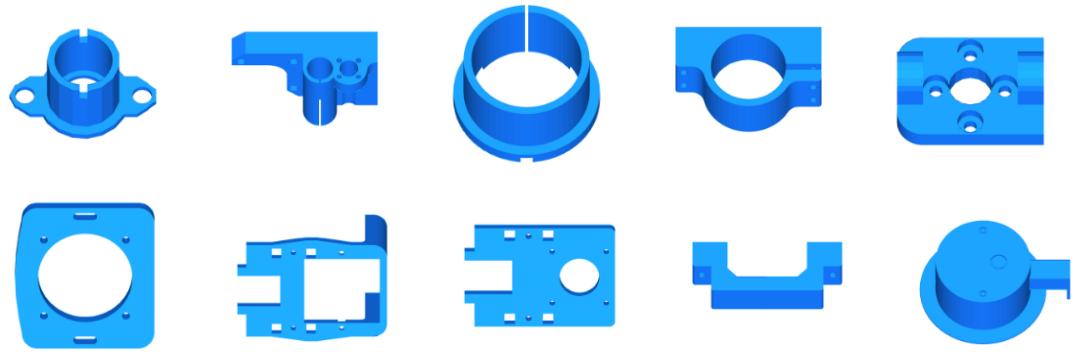

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http://www.thingiverse.com/thing:261498
Voxel | STL | AMF

chess_bishop0.stl
http://www.thingiverse.com/thing:261498
Voxel | STL | AMF

chess_knight0.stl
http://www.thingiverse.com/thing:261498
Voxel | STL | AMF

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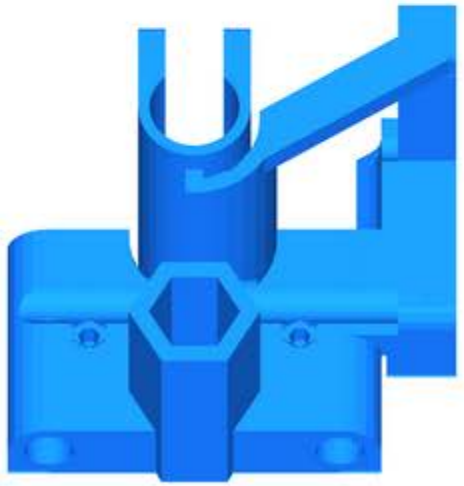
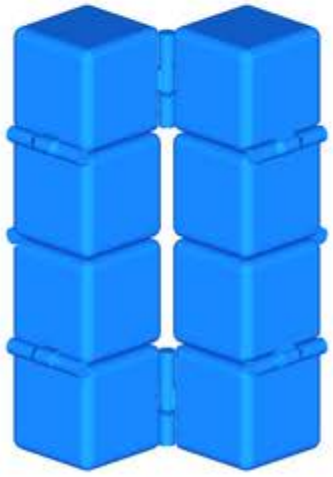
http://www.thingiverse.com/thing:261498
Voxel | STL | AMF





Search Result: “Chess”

Chinese Chess!

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http://www.thingiverse.com/thing:218414
Voxel | STL | AMF

Chinese_chess_back_Elephant.STL
http://www.thingiverse.com/thing:218414
Voxel | STL | AMF

Chinese_chess_back_Soldier.STL
http://www.thingiverse.com/thing:218414
Voxel | STL | AMF

Chinese_chess_back_Cannon.STL
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Voxel | STL | AMF

Cultural Mining

Search Result: “Chess”

Volonoi Chess!

ChessSet_Queen_-_Voronoi.stl
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Voxel | STL | AMF

ChessSet_Knight_-_Voronoi.stl
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Voxel | STL | AMF

ChessSet_Pawn_-_Voronoi.stl
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Voxel | STL | AMF

ChessSet_King_-_Voronoi.stl
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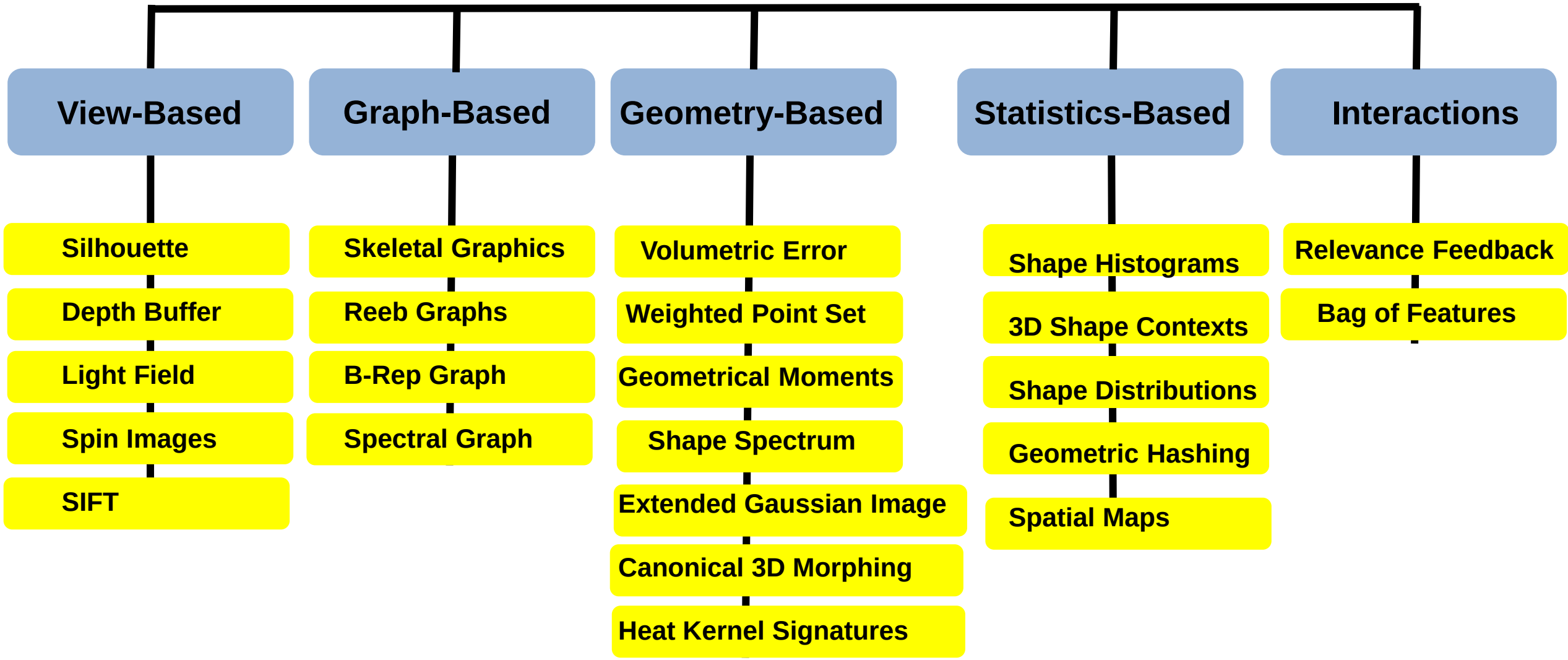
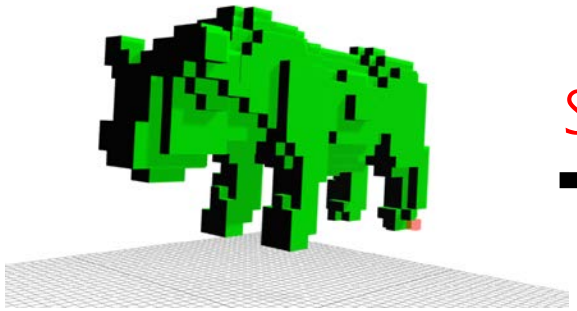
Cultural Mining

Volonoi

3D Object Retrieval Methods



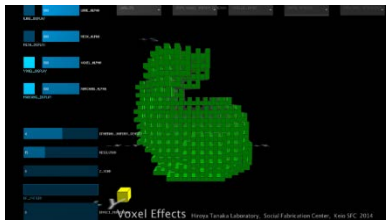
#1. Voxel Format for designing shapes with microstructures

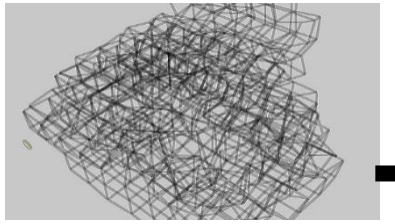


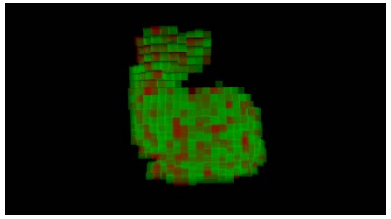
Voxelized Shape

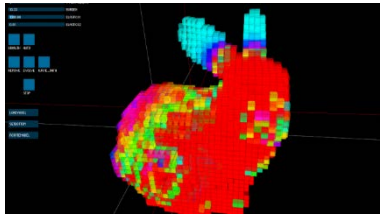
SHAPE

Voxel-Based CAD/CAE/CAM/CAT
(VoxFab)



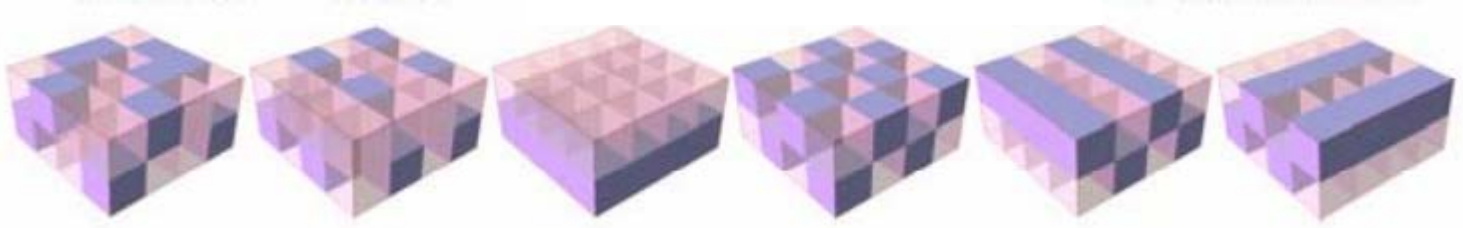






Real-Time Physical Simulation
Topological Optimization

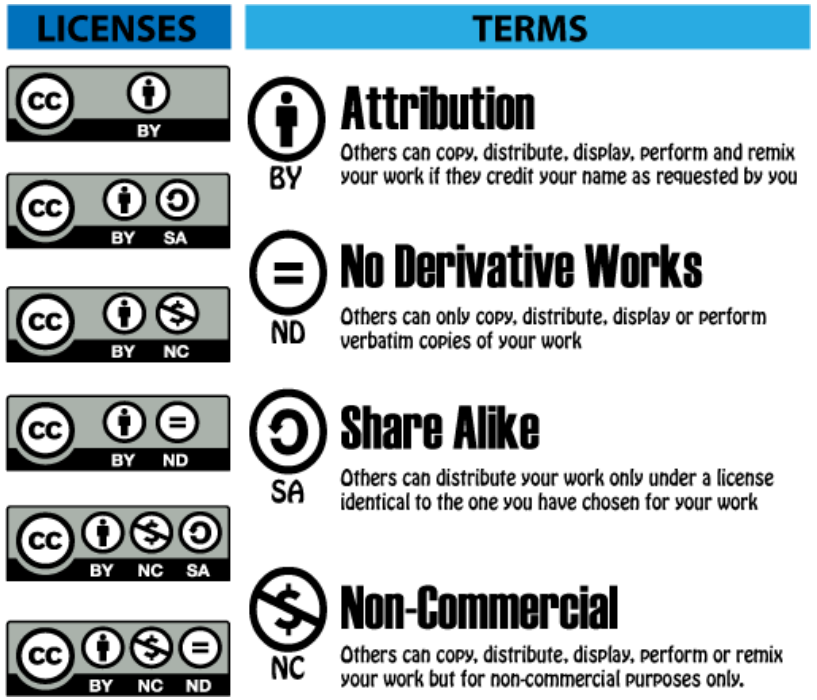
MATERIALS, MICROSTRUCTURE



Internal Microstructure, Different Materials

3D-Printed(Woven) Hybrid Materials

#2. IP(Copyright) Management



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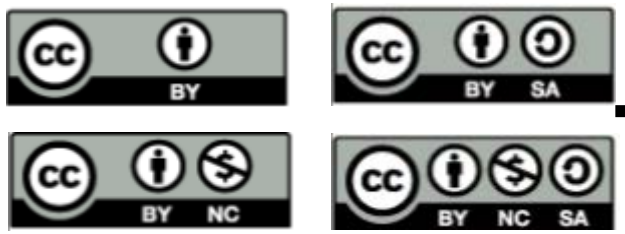
No License → Link to the Original Site



→ Editing and Saving with License

→ Just Saving with License

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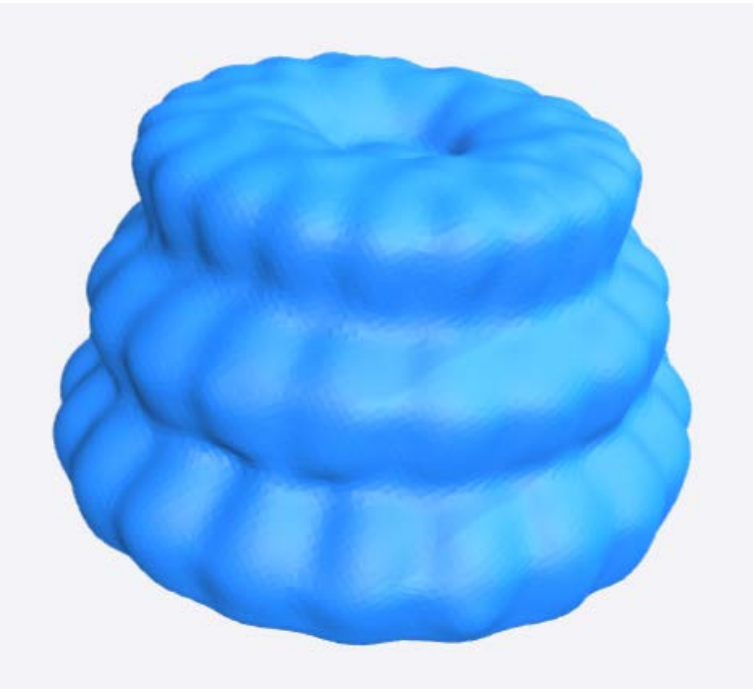
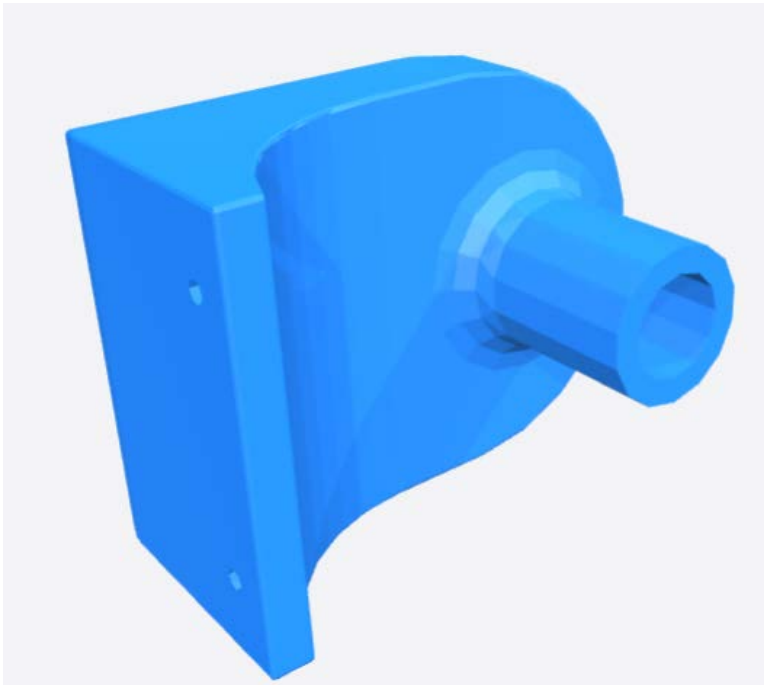
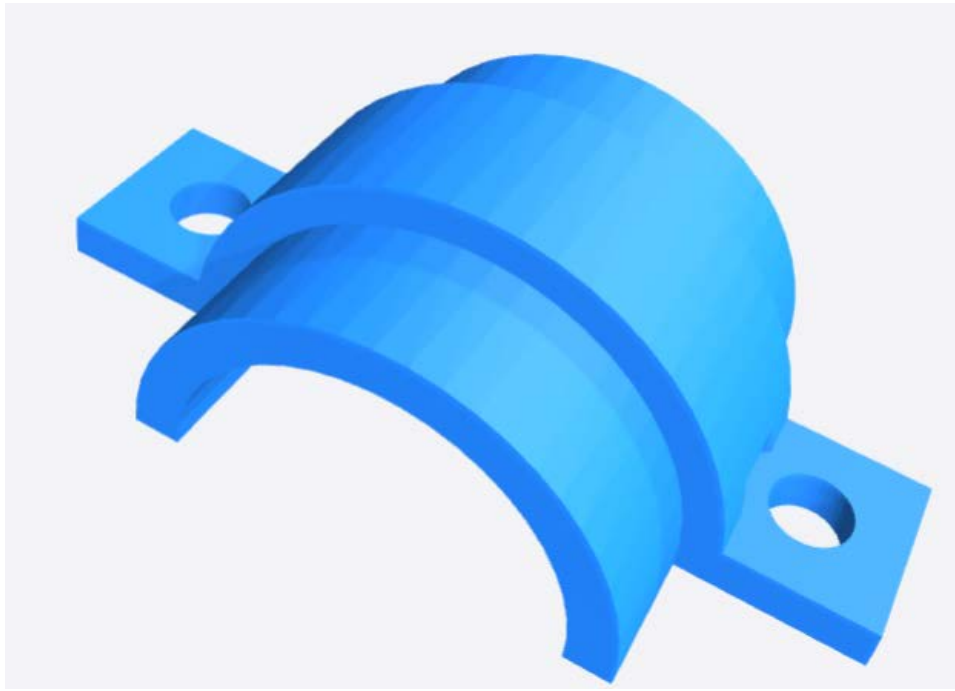
The Limitation of “Keyword” Search

“Shape – Word Matching”







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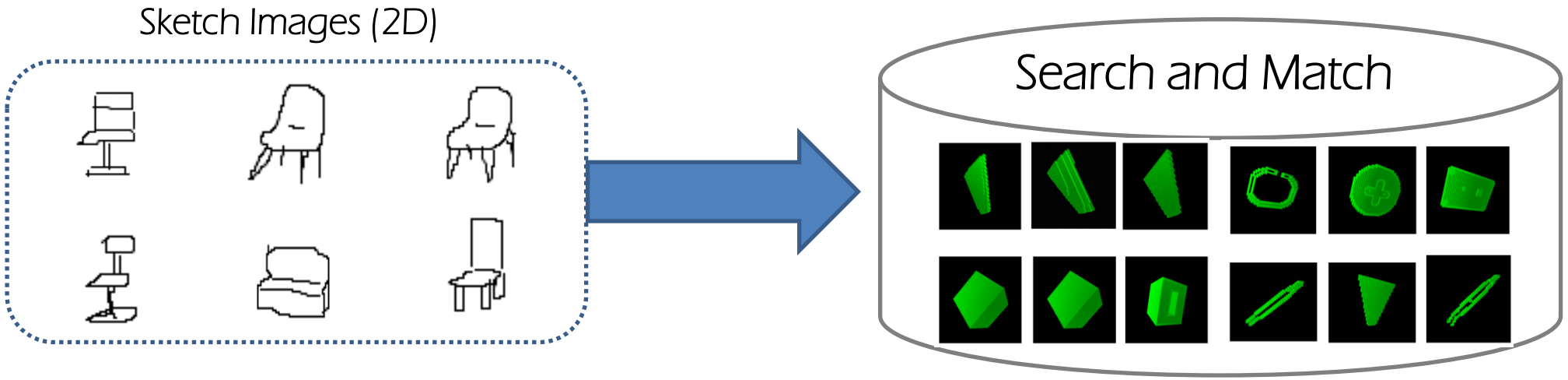
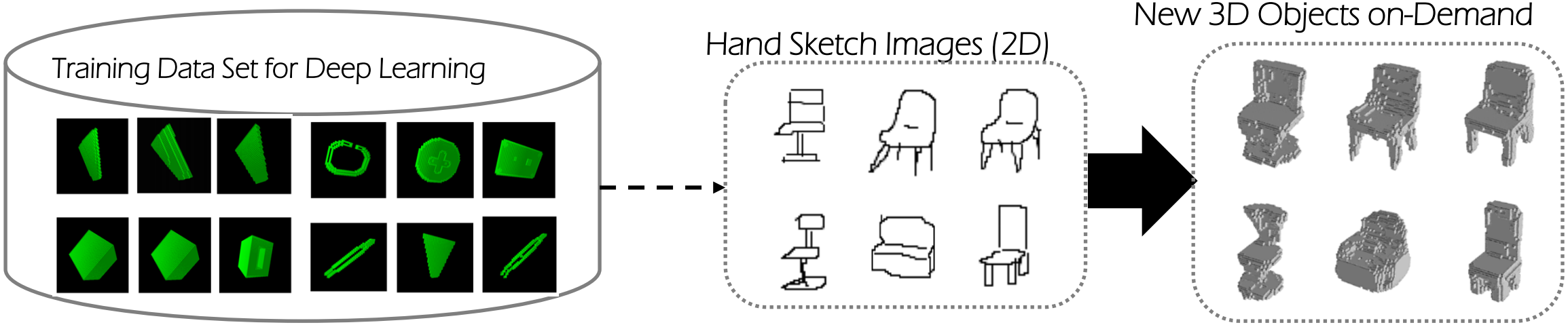
Sketch-Based Object Retrieval[A] v.s. Sketch-Based Object Generation[B]

[A]



[B]



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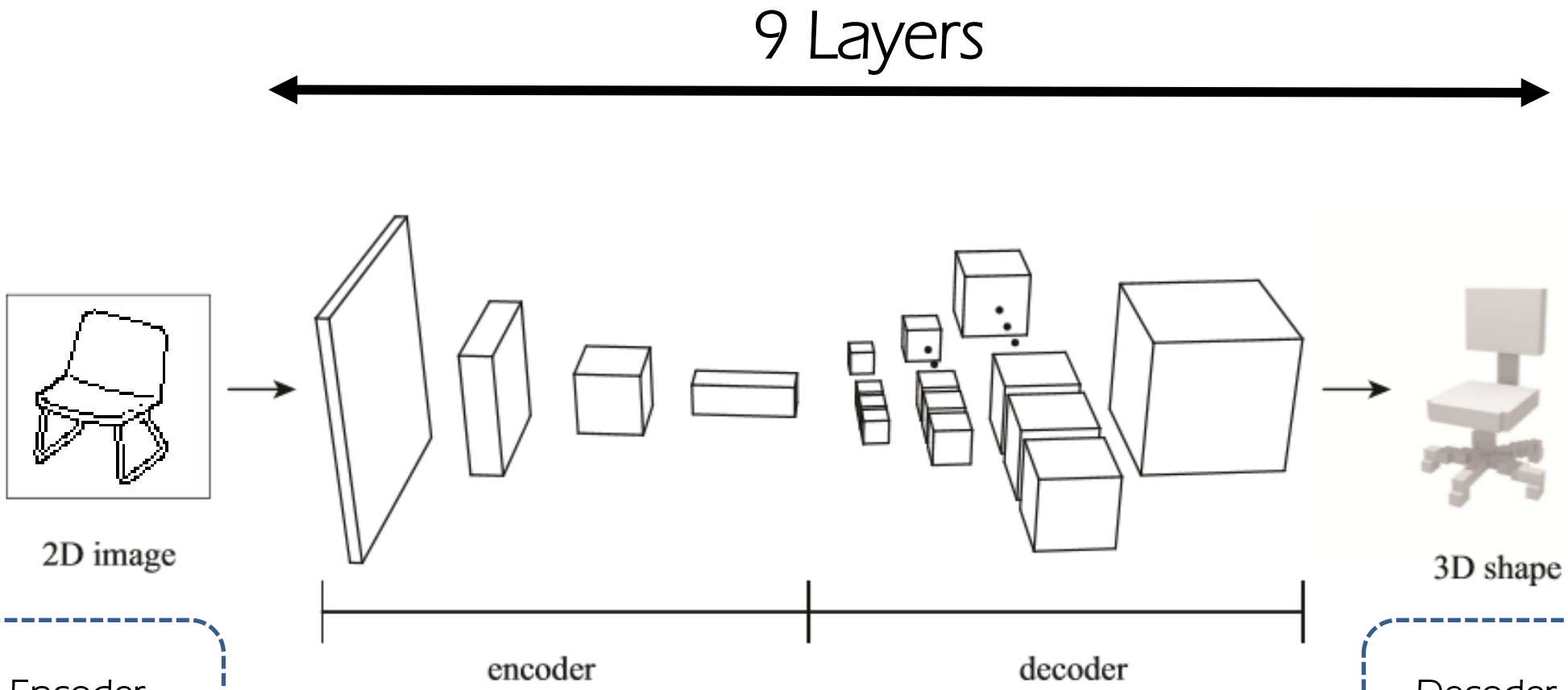
Convolutional Encoder-Decoder Network that is capable of generating a 3D shape directly from a single image of an object



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Training Dataset

"Chair"

2D Wire Models

64×64 Pixels, 32 Angles

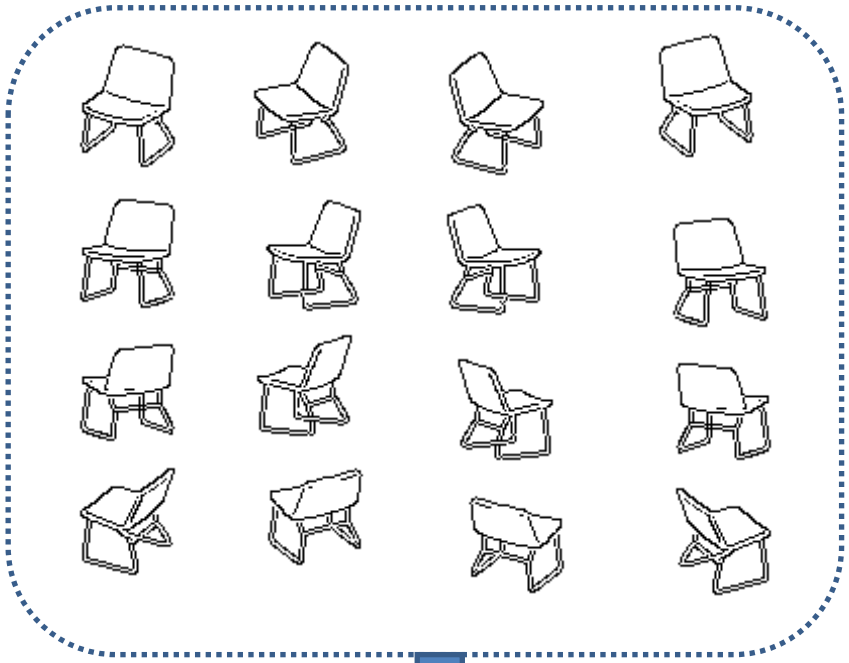
Image Filter

2D Snapshots

Rendering Images

3D Voxel

64×64×64 Voxels



Input to Encoder

Input to Decoder

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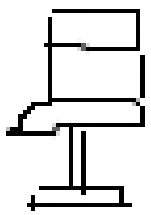
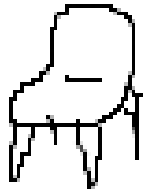
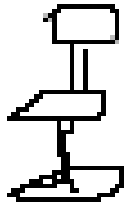
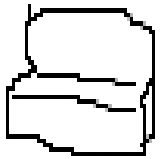
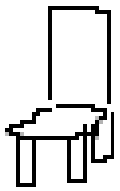
Results (in the case of “chair”)

Hand Sketch (Input)



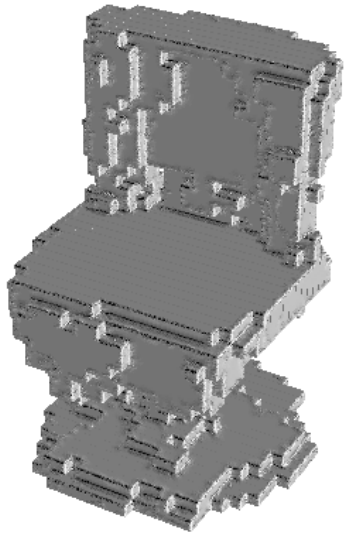
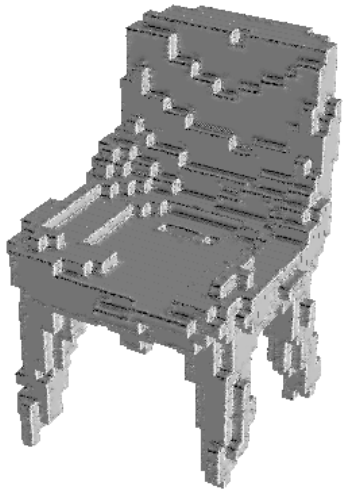
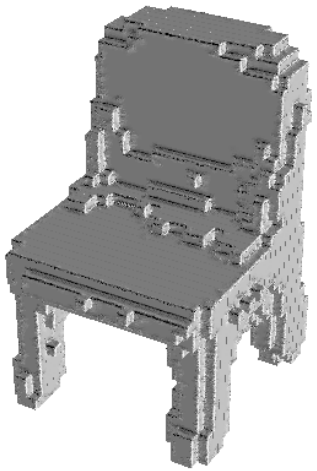
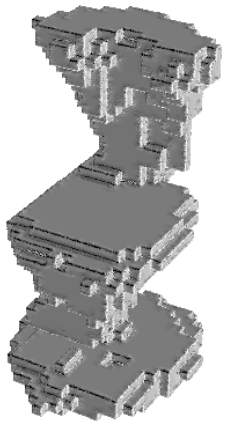
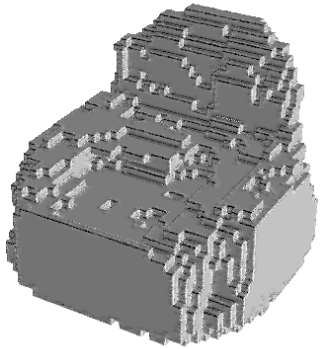
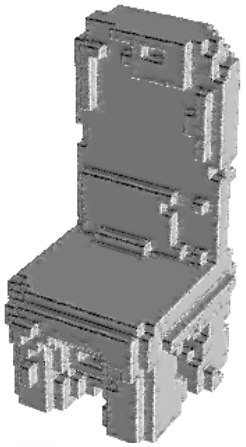
Generates

Generates

Generates

Generates

Generates

3D Voxels (Output)

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ArchiFAB (2.5m High 3D Printer)

Tuning and Improving

Our Algorithm with AEVB (Auto-Encoding Variational Bayes) is useful if the number is more than 200-300

$$\begin{aligned} \mathbf{z} &= \boldsymbol{\mu} + \boldsymbol{\sigma} \odot \boldsymbol{\epsilon} \\ \text{where} \quad \boldsymbol{\mu} &= \text{conv}_1(h) \\ \boldsymbol{\sigma} &= \text{conv}_2(h) \\ \boldsymbol{\epsilon} &\sim \mathcal{N}(\mathbf{0}, \mathbf{I}) \end{aligned}$$

$$\mathcal{L} = -\log p(\mathbf{y}|\mathbf{z}) + D_{KL}(q(\mathbf{z}|\mathbf{x}) \| p(\mathbf{z}))$$

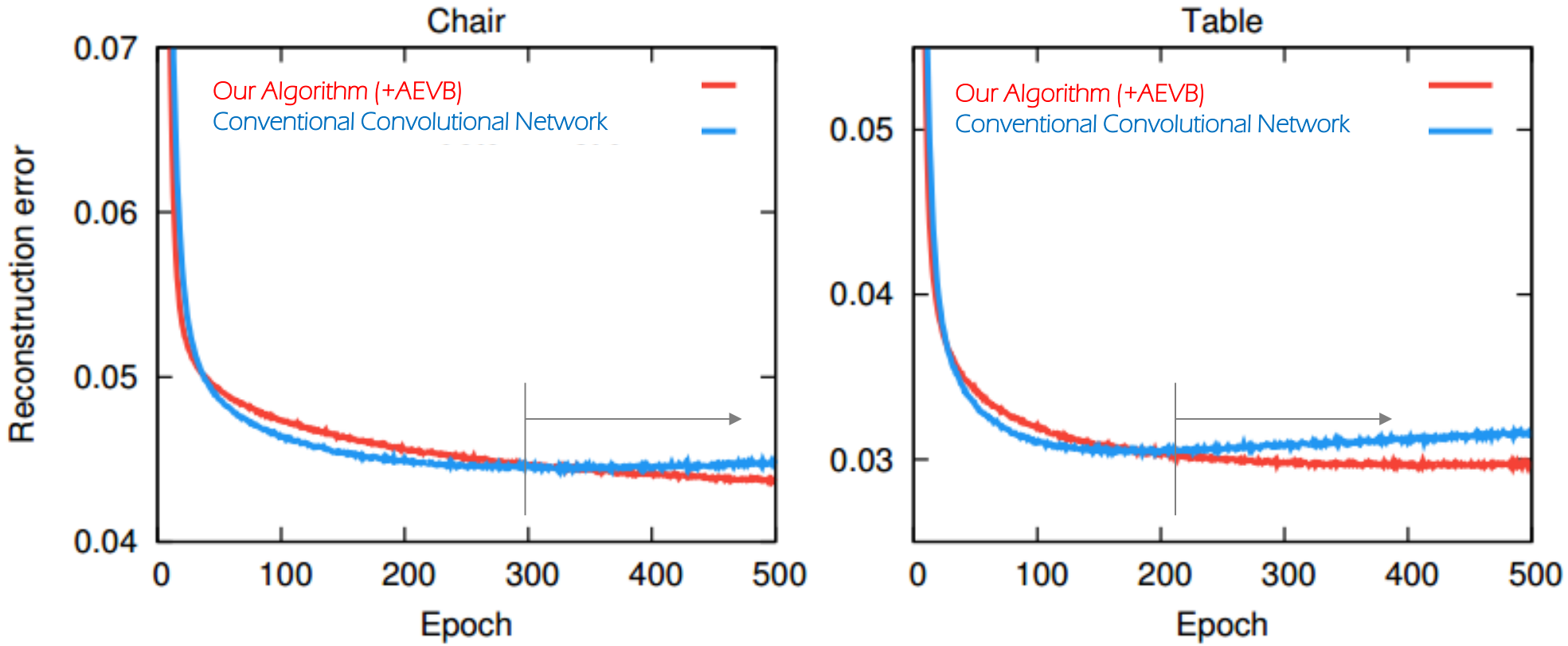

Figure 8: Comparing reconstruction mean squared errors on the test sets of chairs and tables model (probabilistic network) and deterministic one. See section 4.5 for details.

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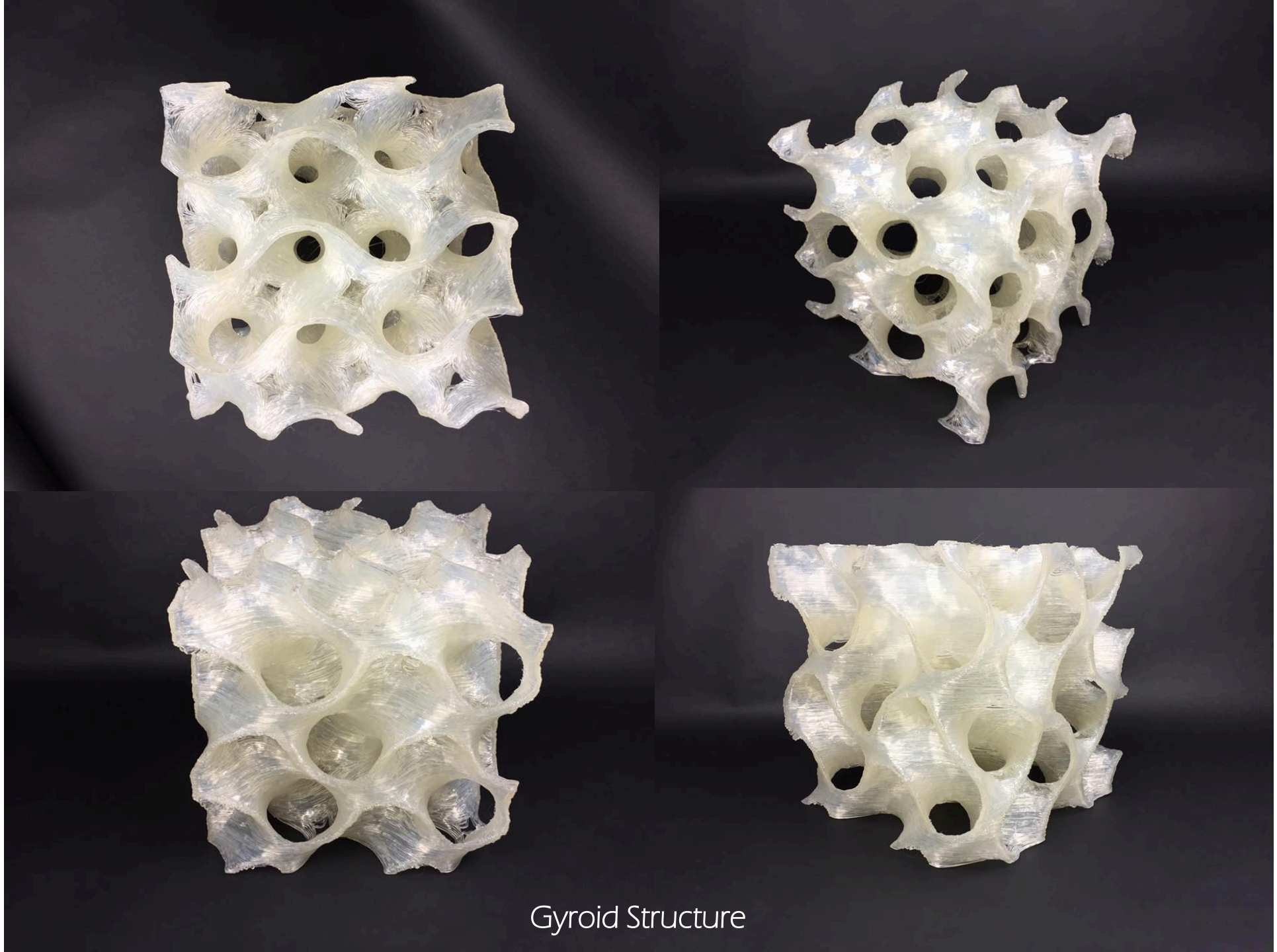
Architecture Design : Emu Masuyama (Keio University)



Gyroid Structure

Conclusions

We implemented a cross-search Engine for 3D Objects(STL files), and Deep Learning system for generating new 3D Objects from hand sketches.

Our prototype system is available at: http://fab3d.cc

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