Taking (BioMedical) Visualization Off the Screen

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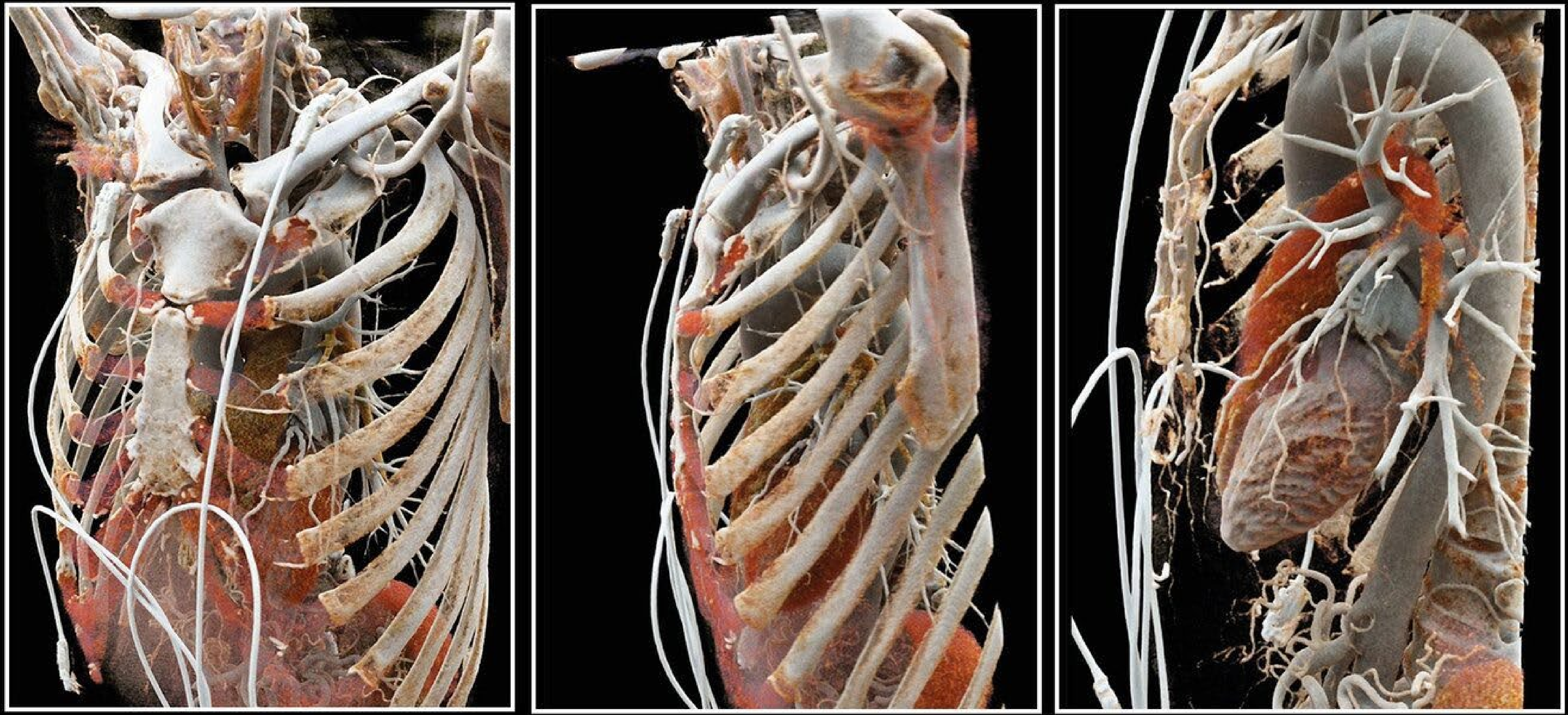
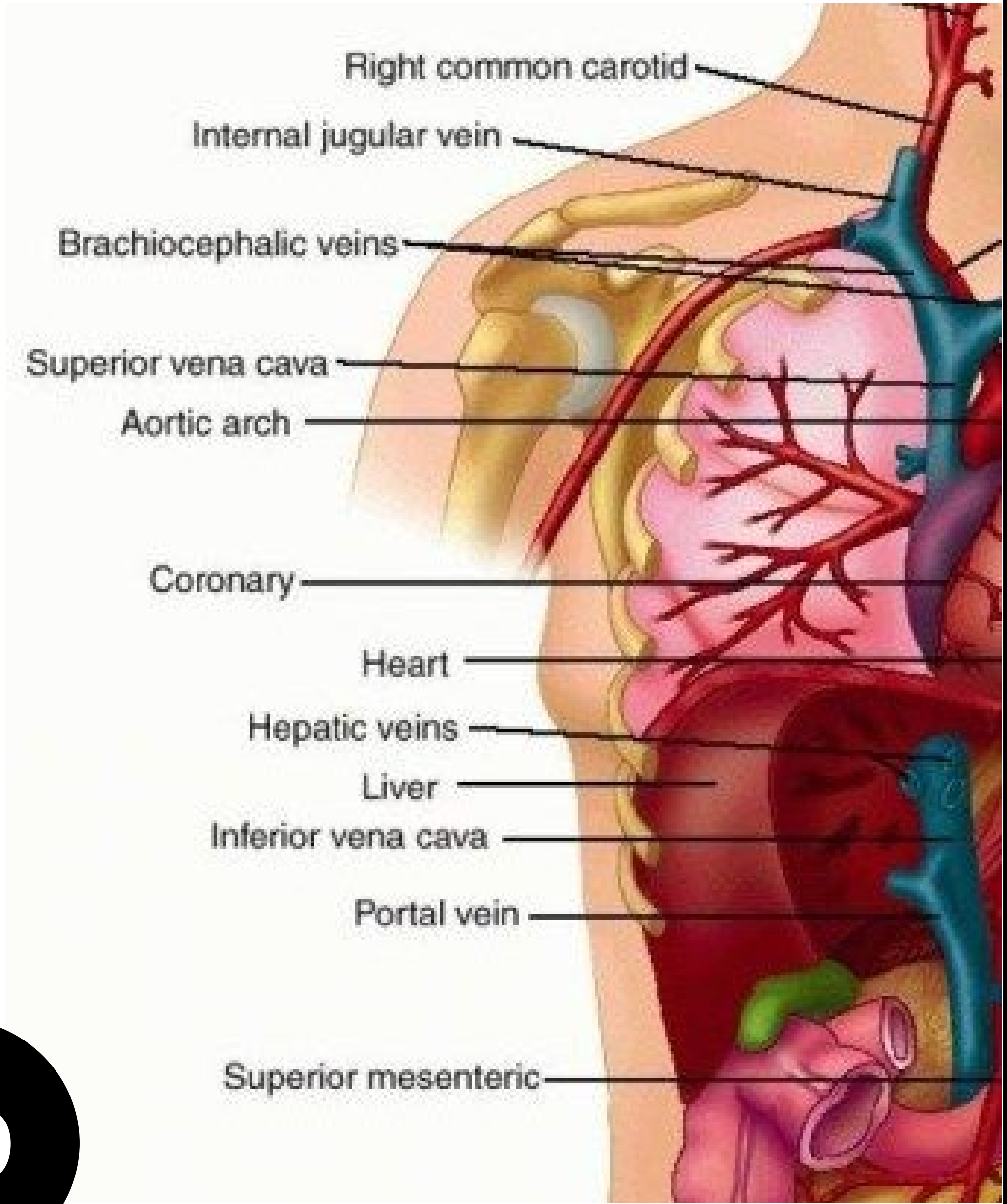
TU Wien, Austria

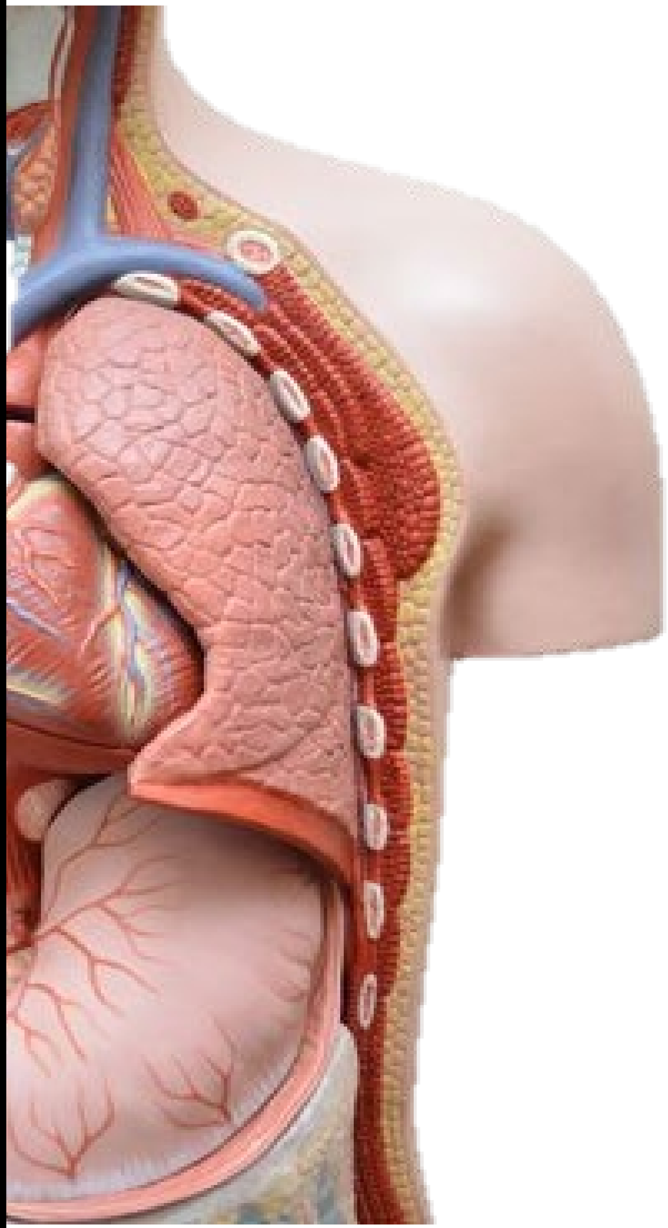


Source: Siemens Healthcare

The Anatomy Lesson of Dr. Nicolaes Tulp – Rembrandt (c. 1632)


Right common carotid
Internal jugular vein
Brachiocephalic veins
Superior vena cava
Aortic arch
Coronary
Heart
Hepatic veins
Liver
Inferior vena cava
Portal vein
Superior mesenteric

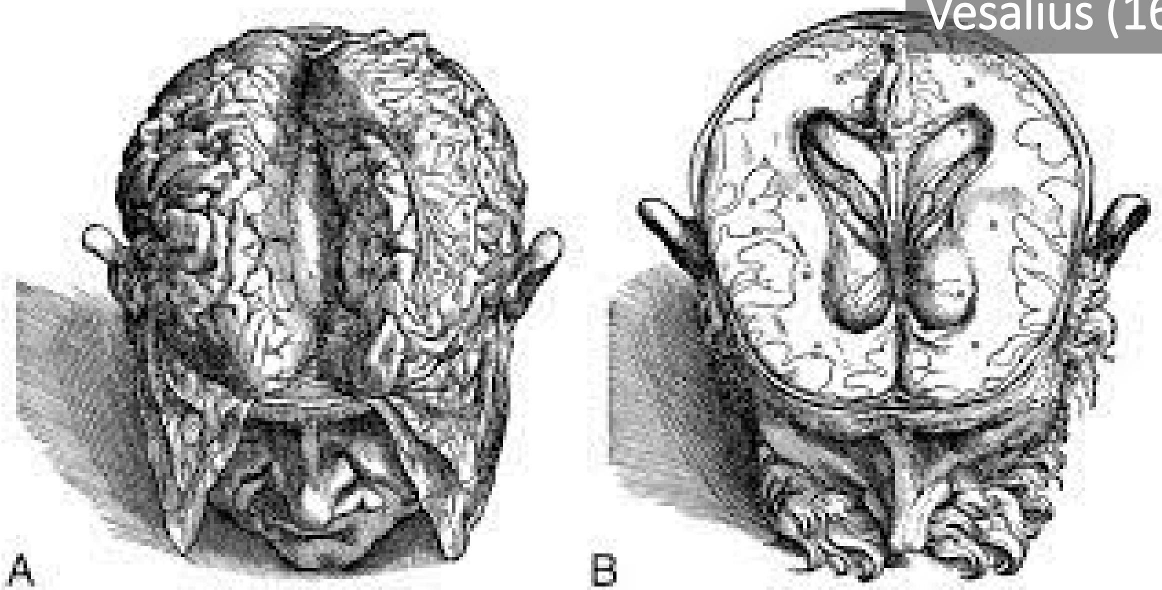
2D



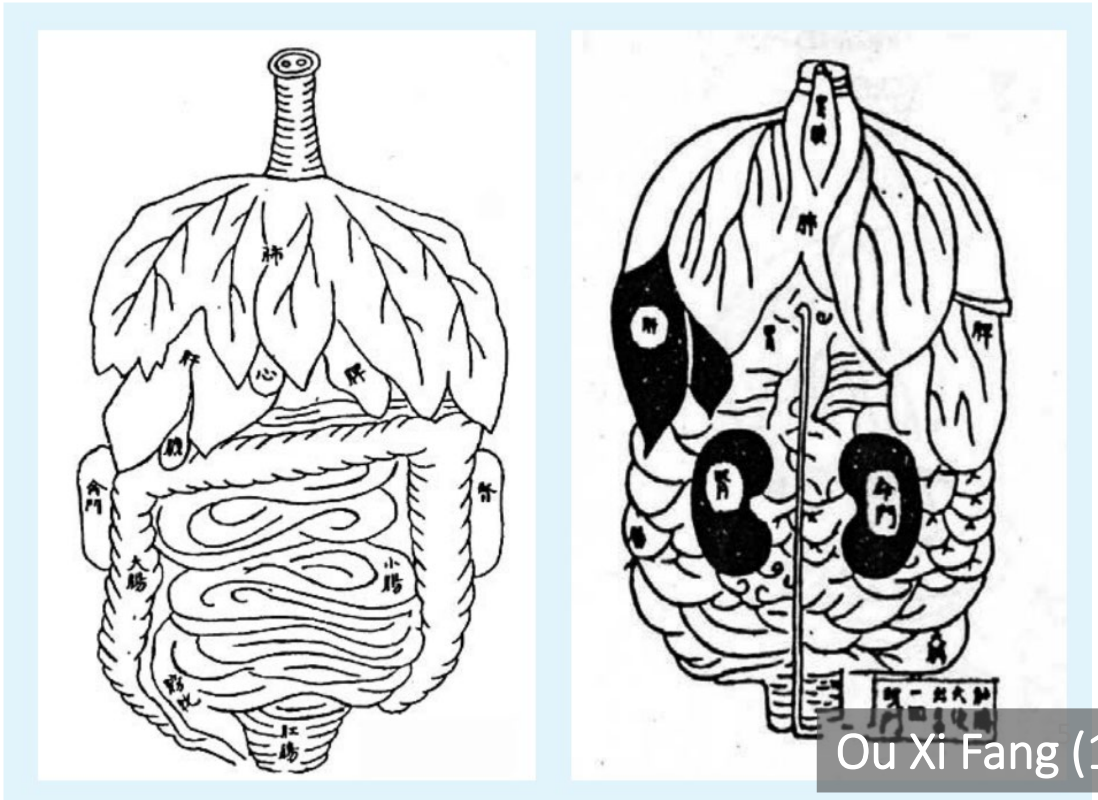
3D

2D

Da Vinci (15th c.)



Vesalius (16th c.)



Ou Xi Fang (10th c.)

3D

Papier-Mâché Brain (18th c.)

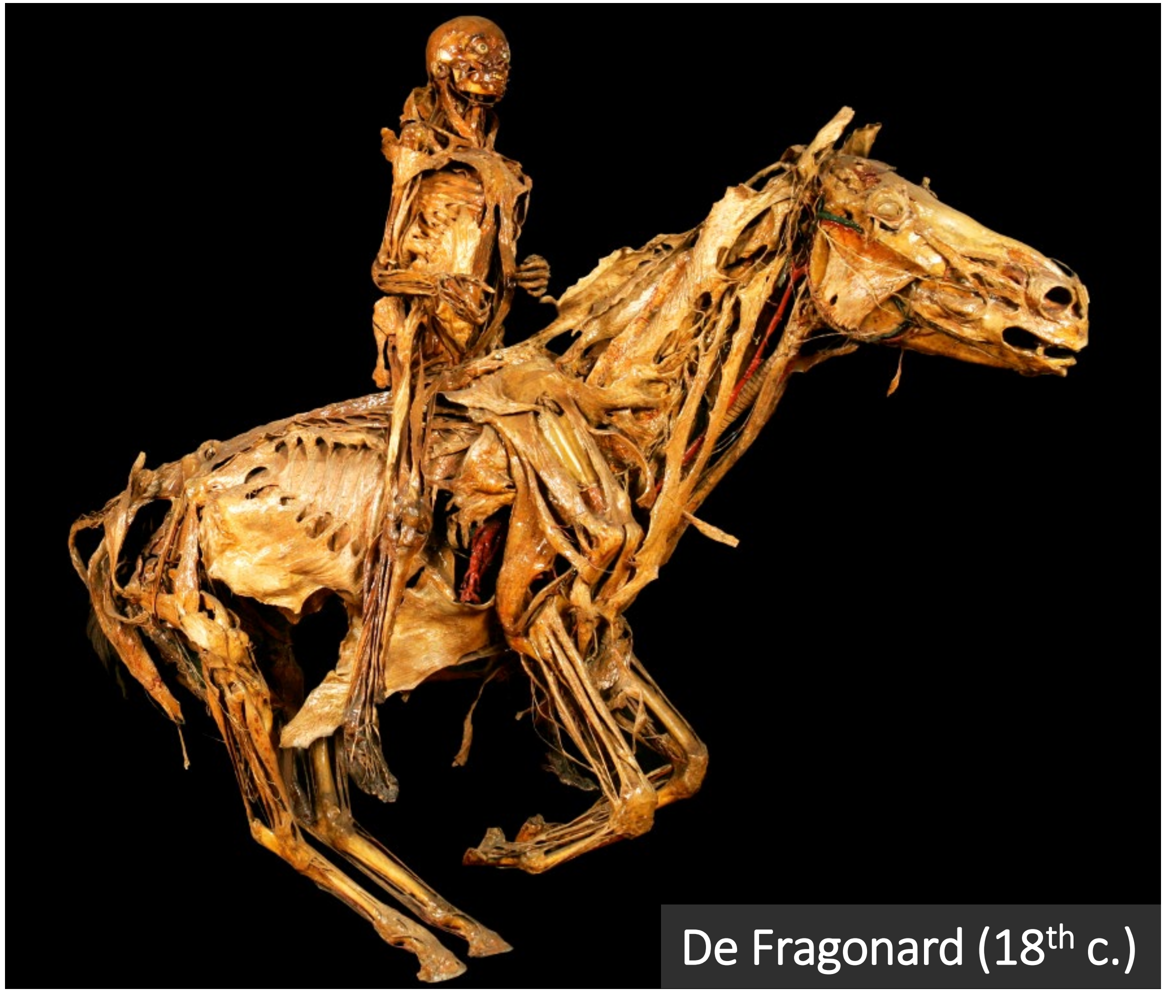
Wax Sculpture (18th c.)

The Mother (18th c.)

Anatomical Venus (18th c.)

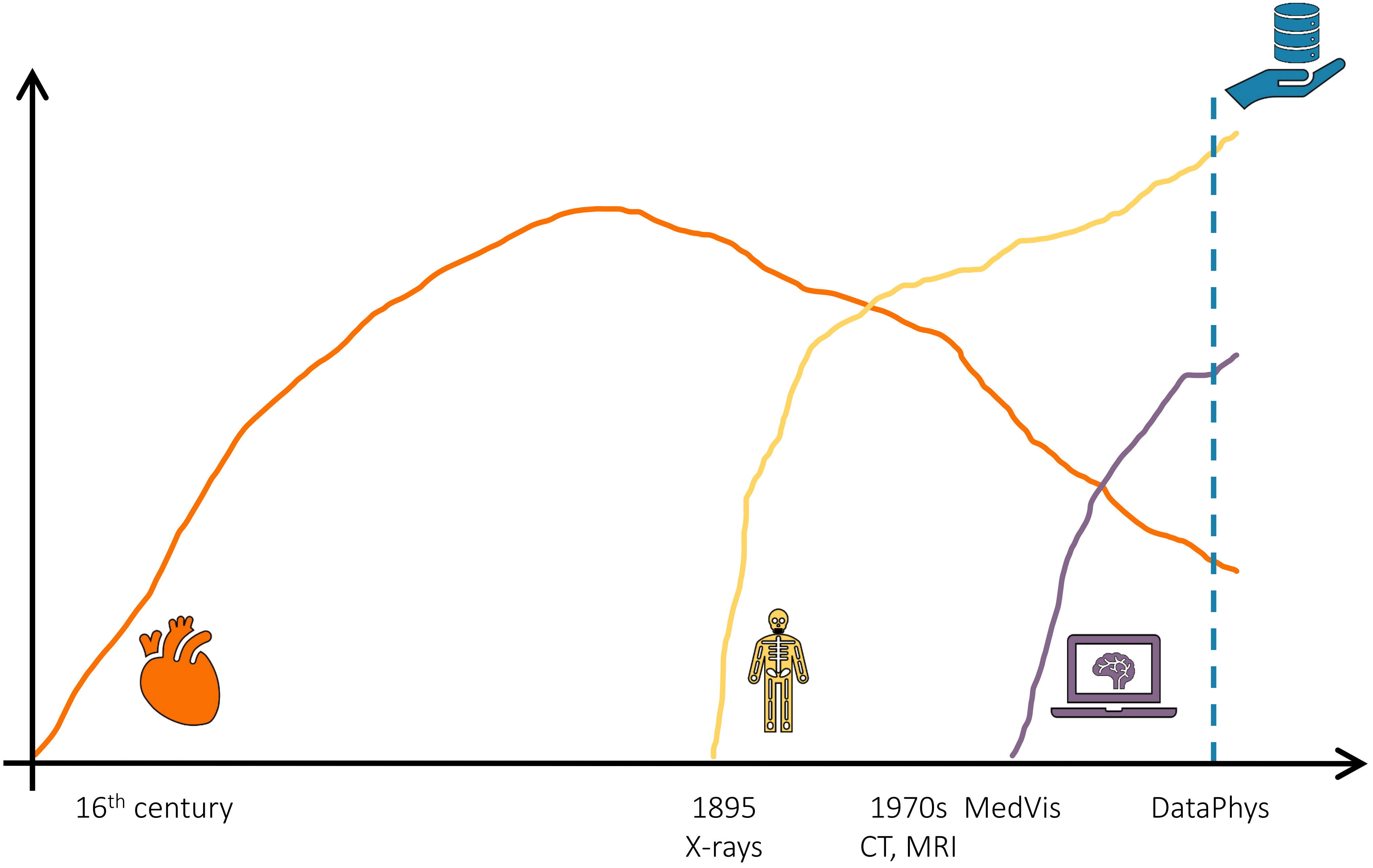
Moulagen (18th c.)

3D



De Fragonard (18th c.)

Von Hagens Body World Exhibit (21st c.)

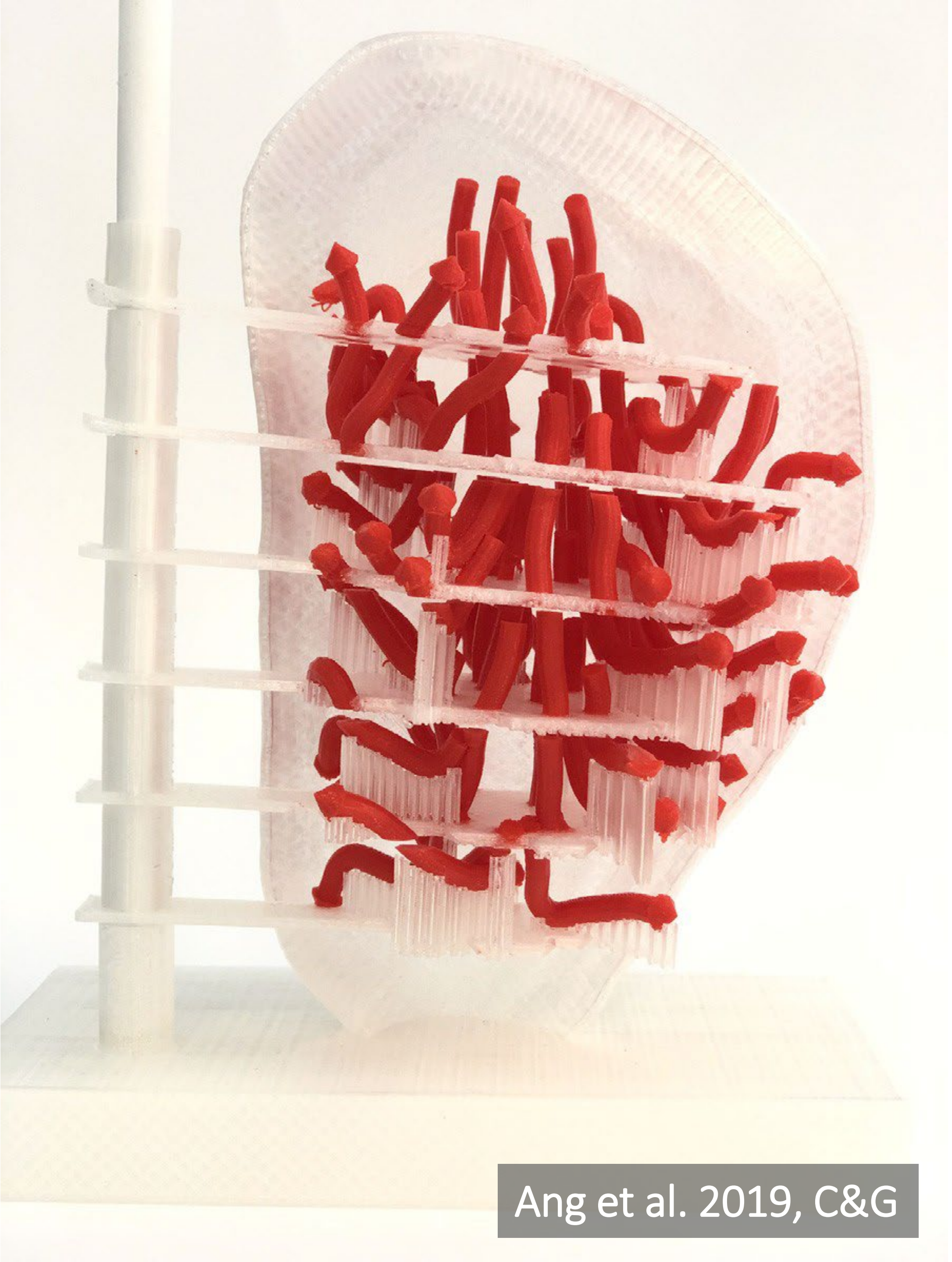

16th century
1895
X-rays
1970s
CT, MRI
MedVis
DataPhys

Source: Siemens Healthcare

Data Physicalization is...

...a rich and vast research area that studies the use of physical artifacts to convey data.

Dragicevic et al. 2021, HCI Handbook



Ang et al. 2019, C&G

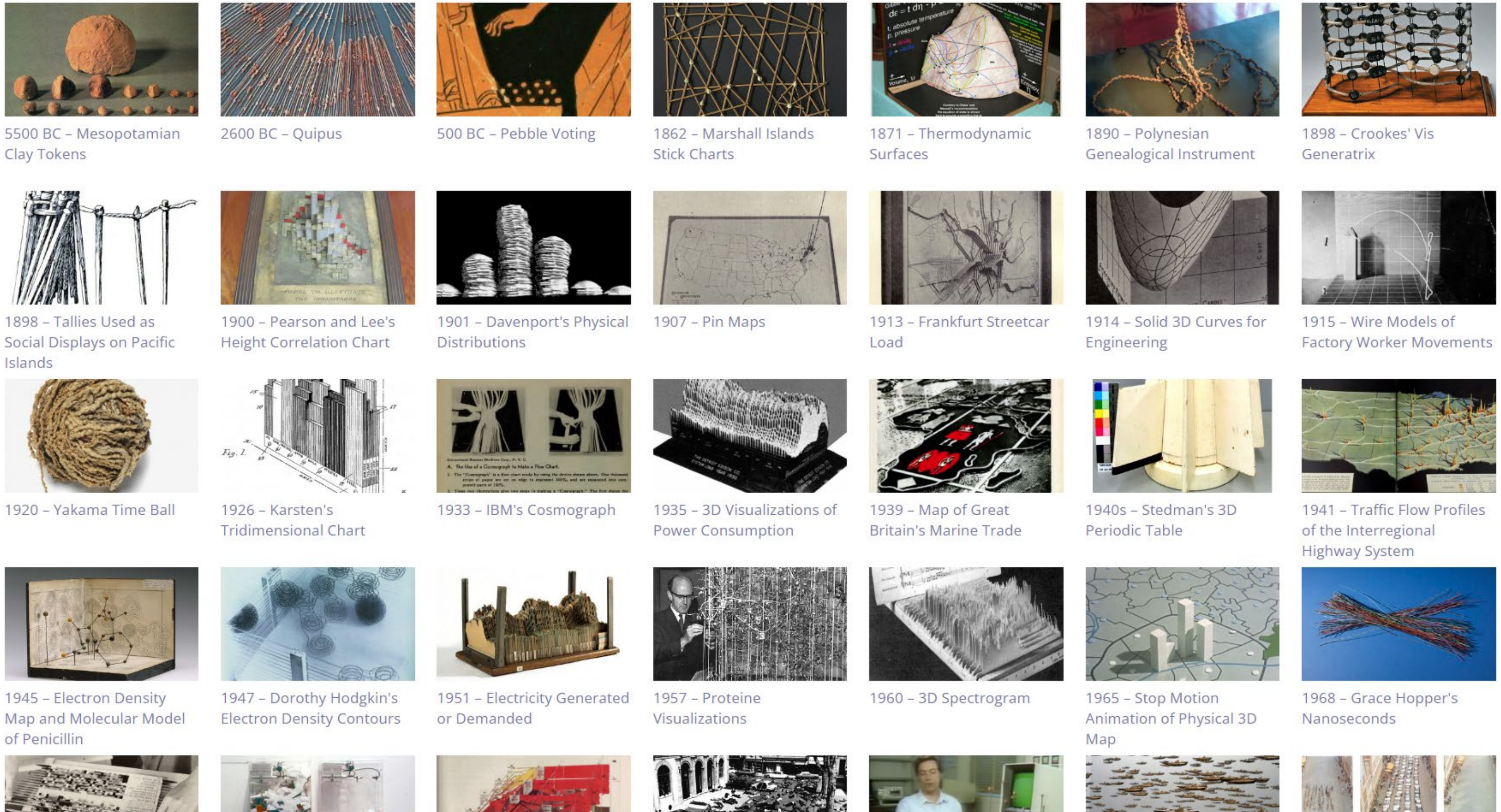
Gallery of Physical Visualizations

and Related Artifacts

This is a chronological gallery of physical visualizations and related artifacts, maintained by Pierre Dragicevic and Yvonne Jansen. Thanks to our contributors. If you know of another interesting physical visualization, please **submit it**!
This list currently has 370 entries. You can also get notified of new entries through Twitter.

Search:

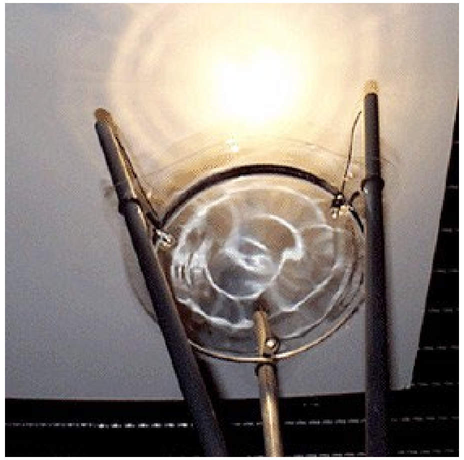
List view | Passive physical visualizations (214) | Active physical visualizations (43) | Physical models (35) | Measuring instruments (11) | Interactive installations (7) | Enabling technologies (29) | Other (7) | Uncertain (24)



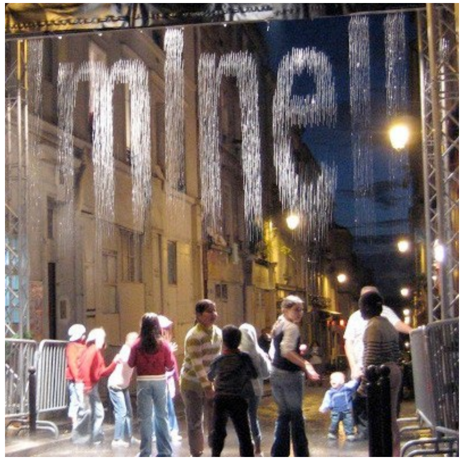
Not only for medical data!

http://dataphys.org/list/gallery/

Categories



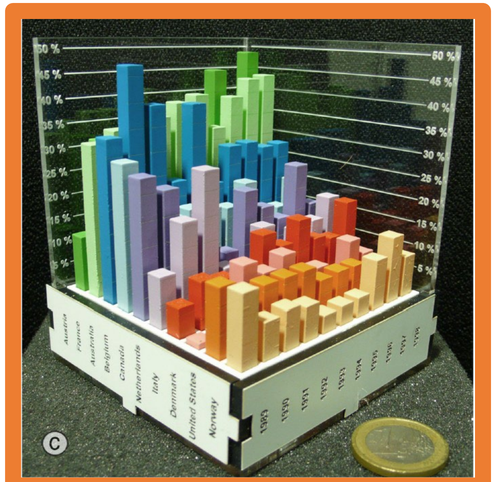
Ambient Display



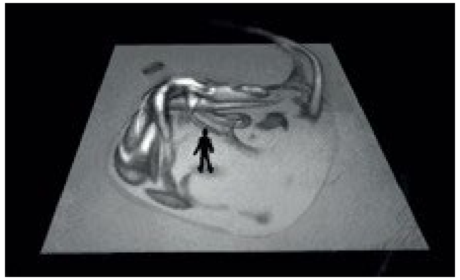
Pixel Sculpture

Object Augmentation

Wearable Visualization

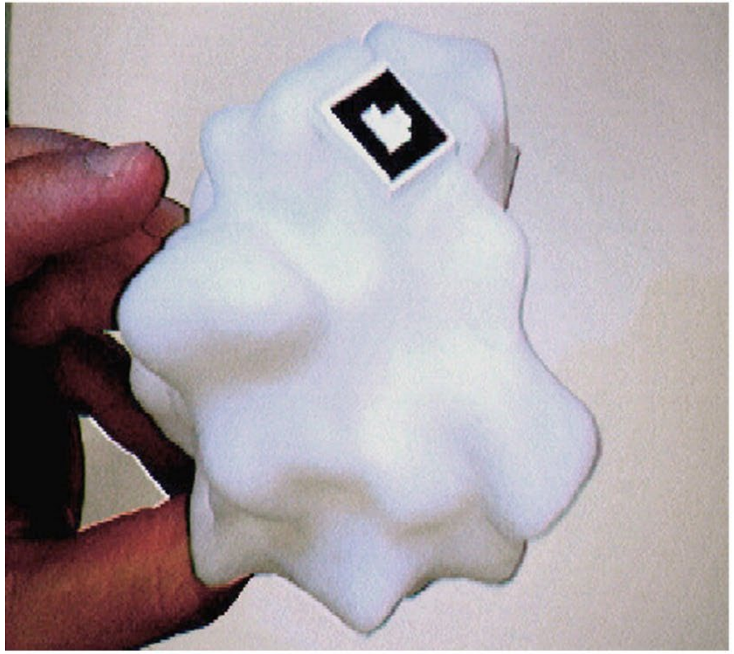


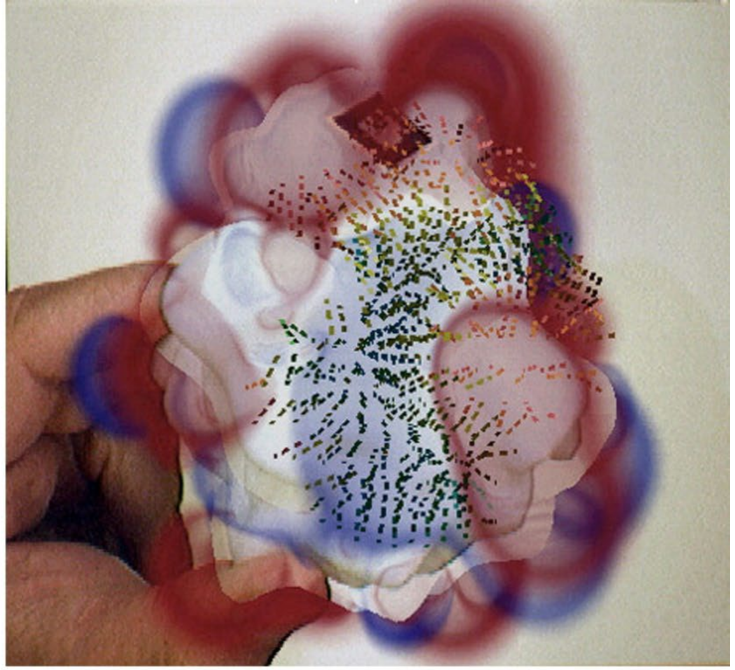
Data Sculpture

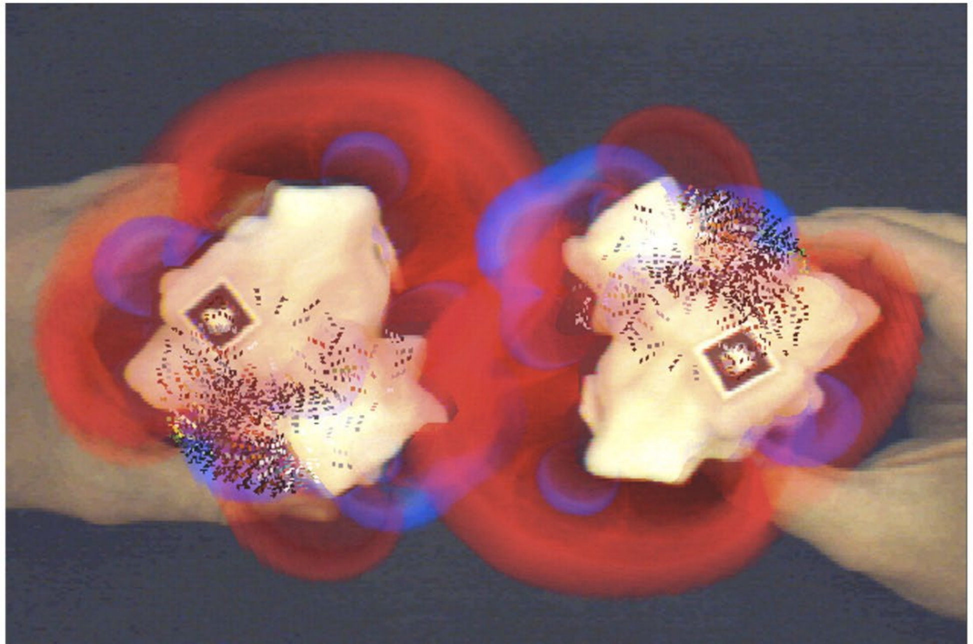


Modality Display

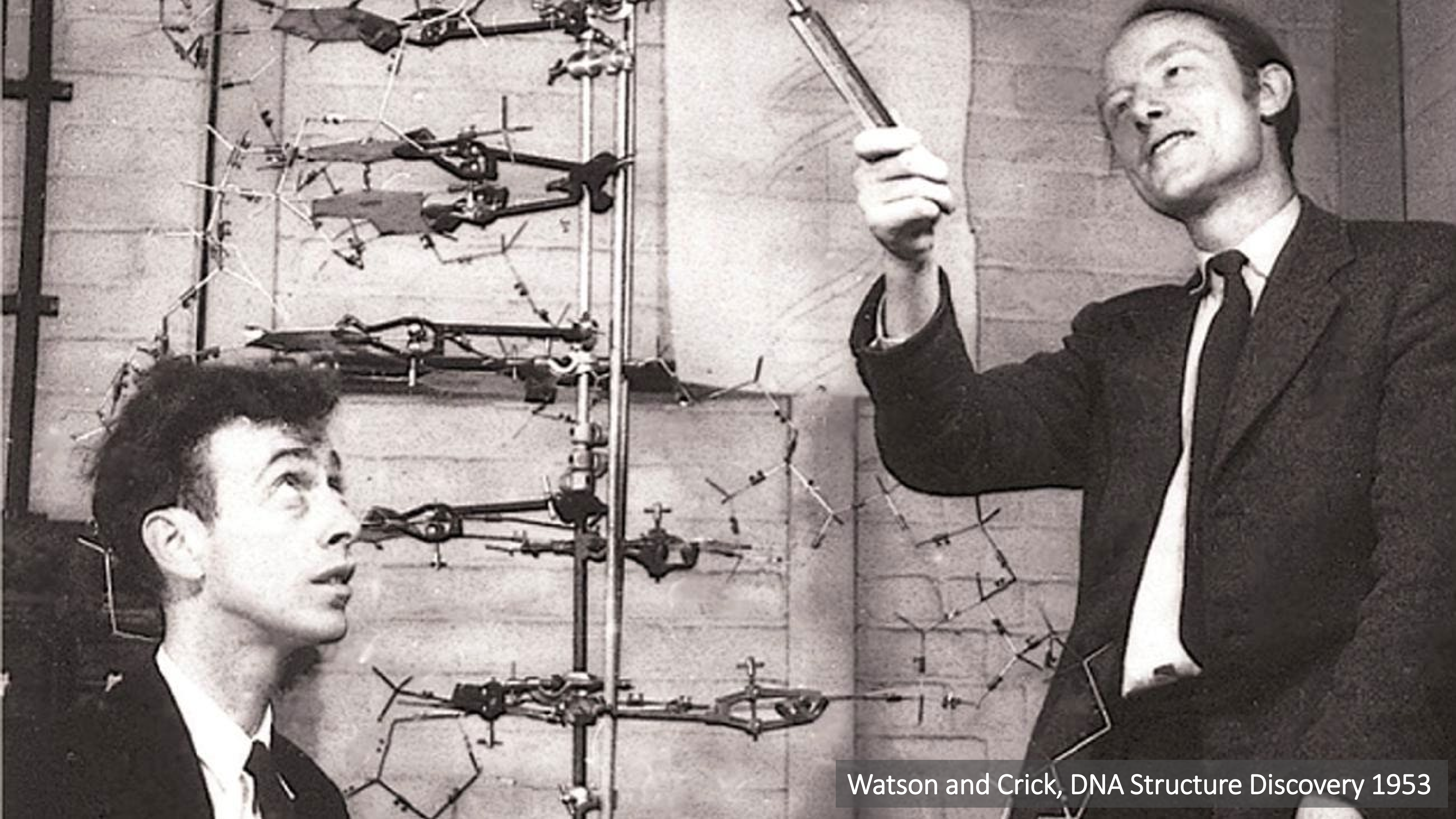
VirtualiTee







Gillet et al. 2005, Structure



Watson and Crick, DNA Structure Discovery 1953

expensive

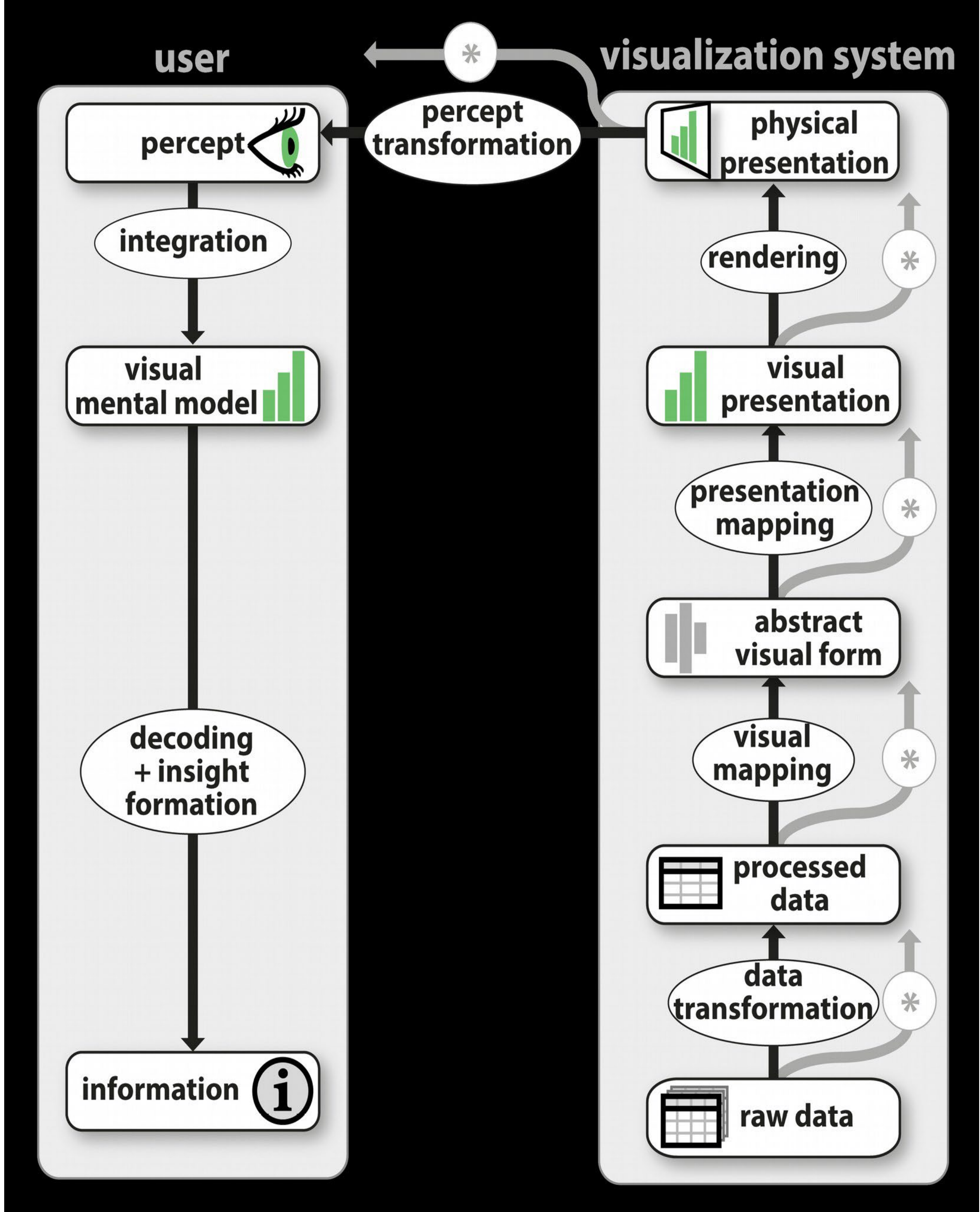
complex

time-costly

A 3D printed heart
(costs around $700-1000)

From Data To Sculpture

- Extension of info vis pipeline (Jansen et al. 2013, CHI)
- Adds information extraction on user side:
  - How is information processed?
  - What interactions are possible?



Two Recent Examples of Data Sculptures

Schindler et al. 2020, IEEE Vis

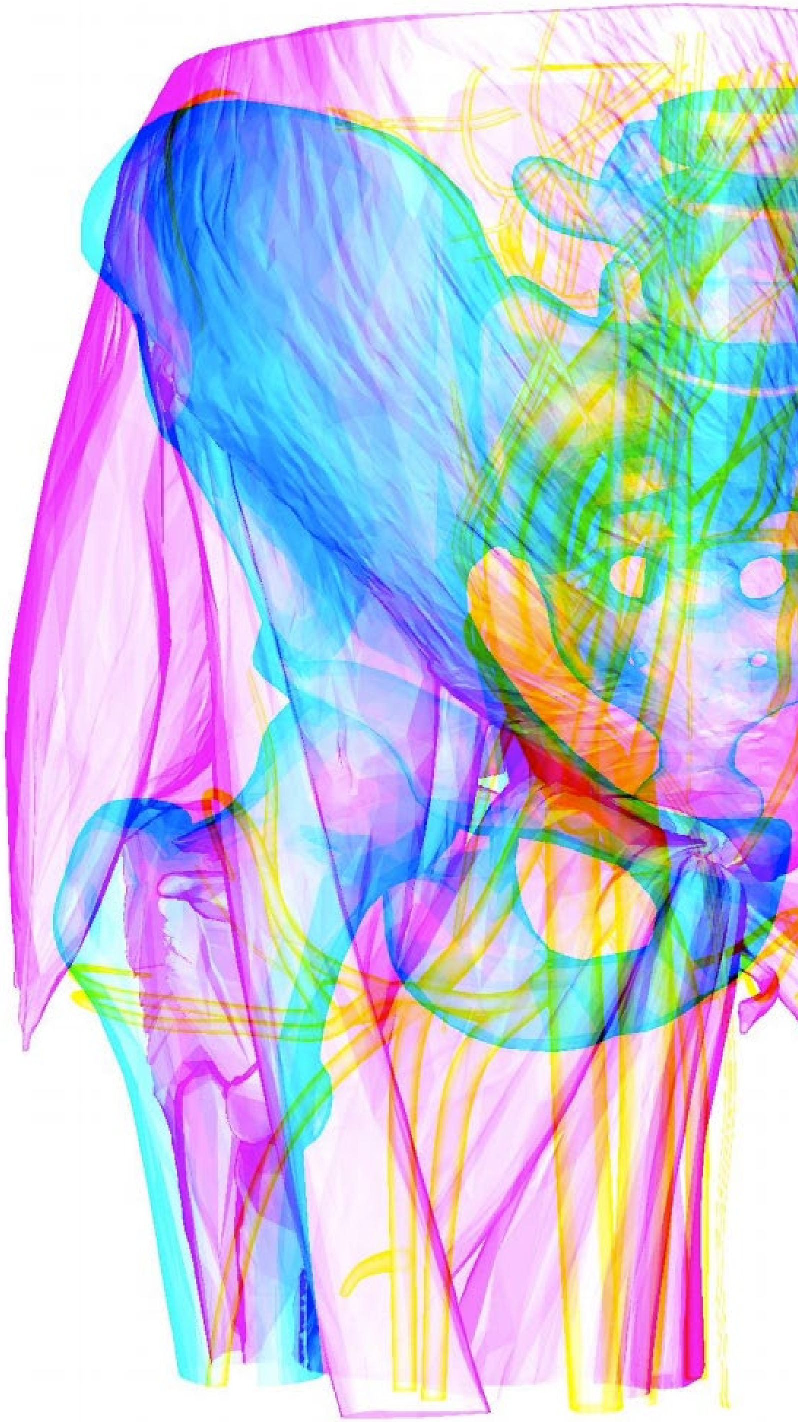
Schindler et al. 2022, CGF

The Anatomical Edutainer

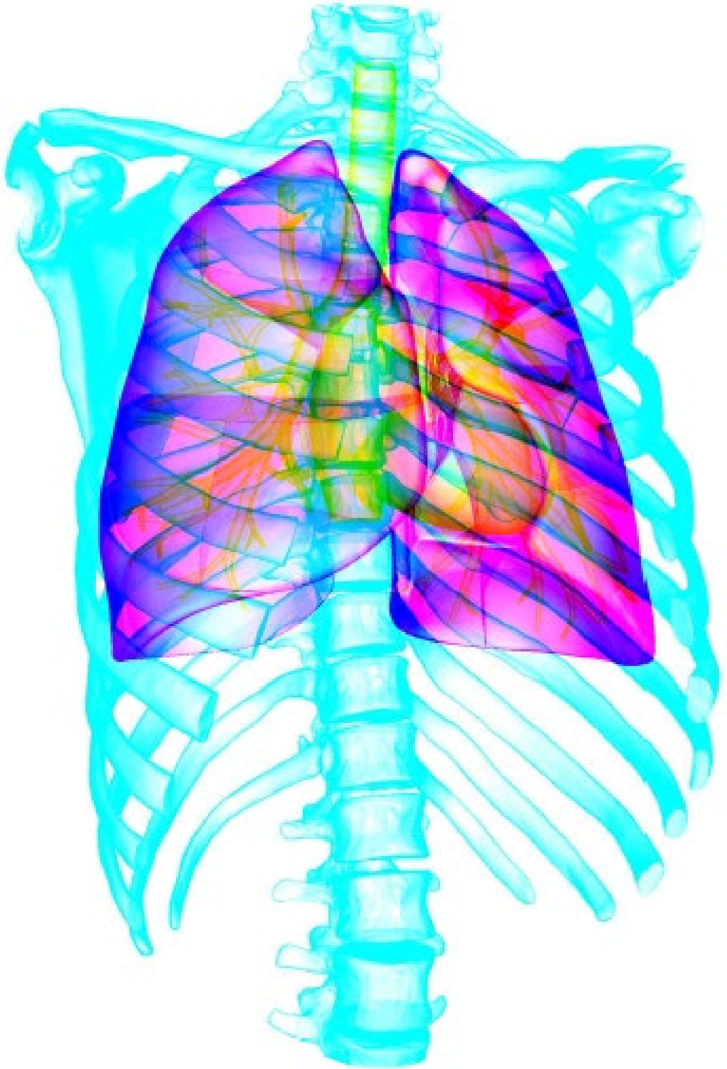
Marwin Schindler, Hsiang-Yun Wu, Renata G. Raidou

Best Short Paper at

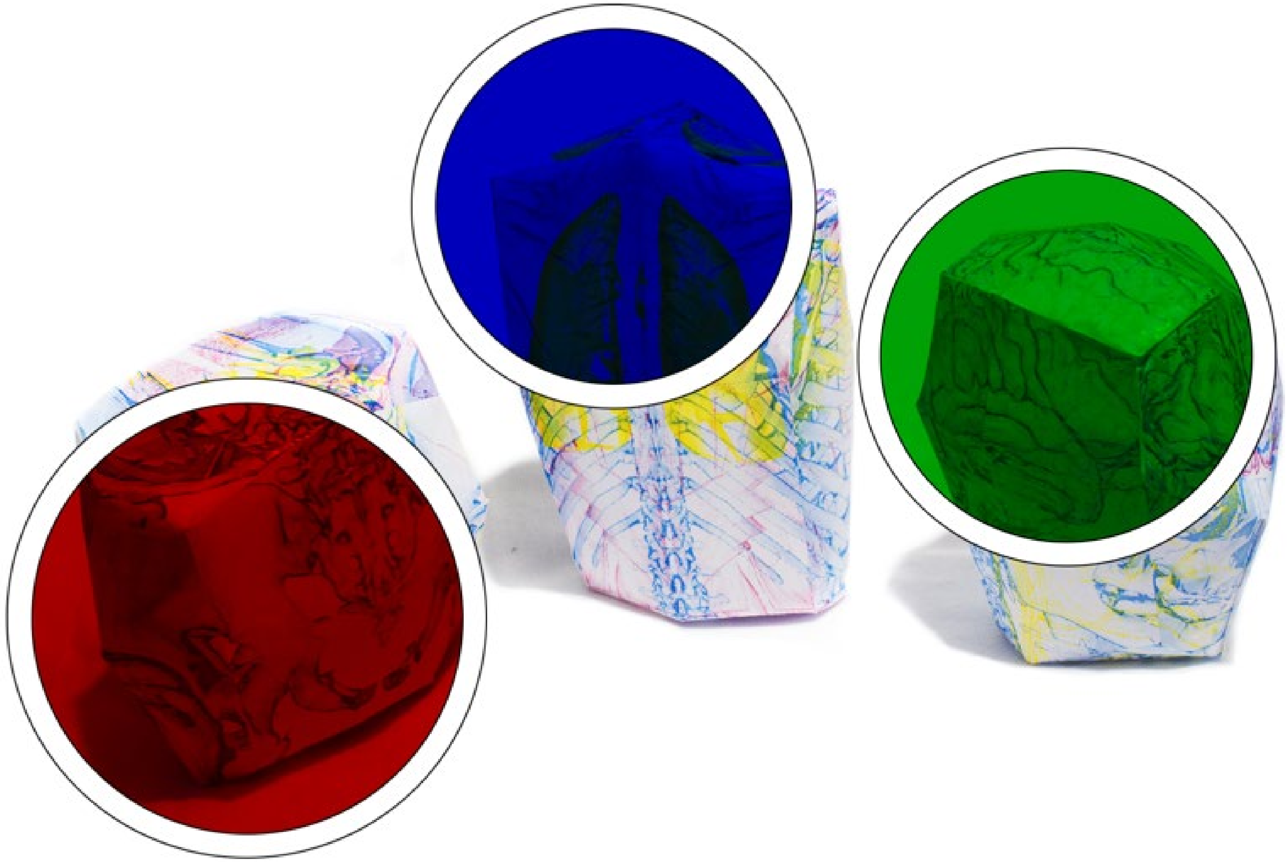
VIS2020

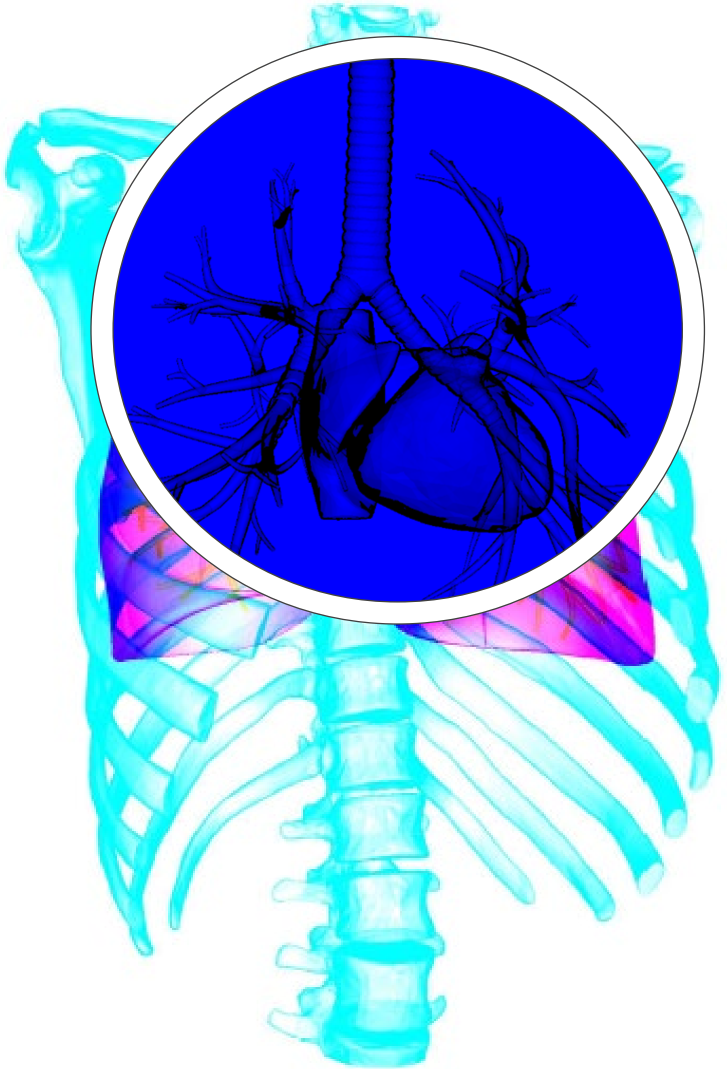


Motivation

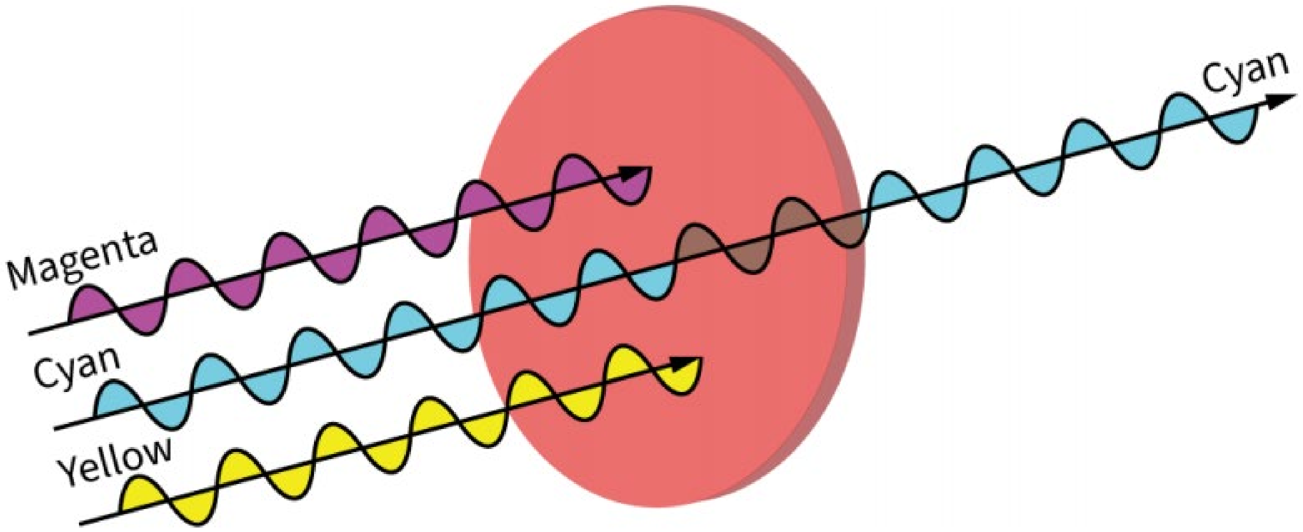


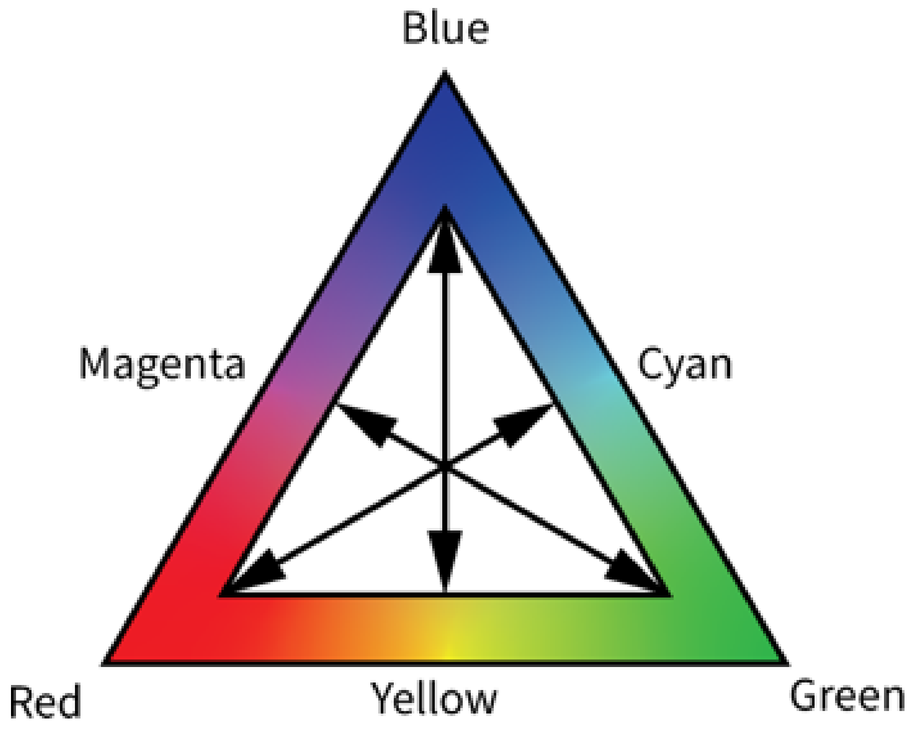
Motivation



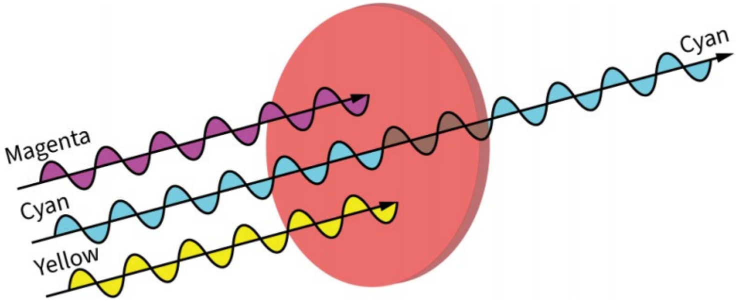


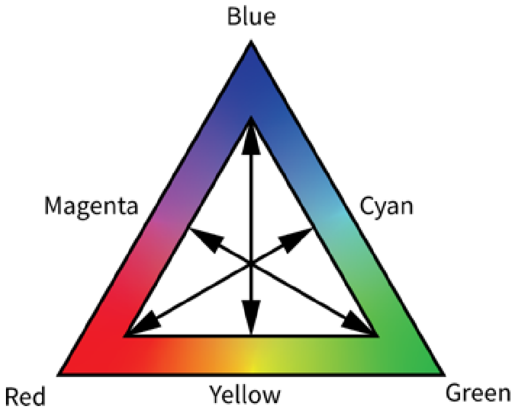
1st Concept: Light Absorption





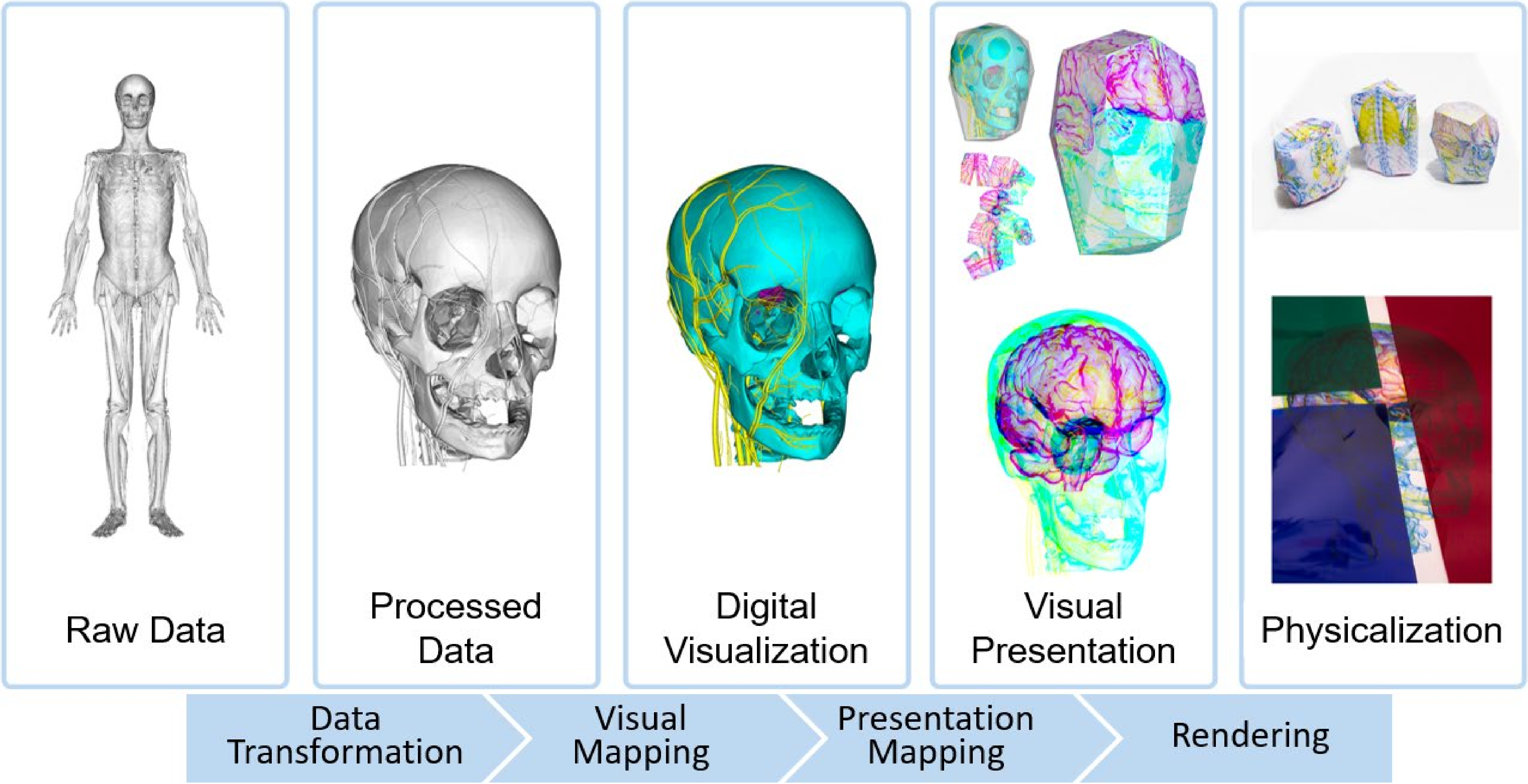
1st Concept : Light Absorption



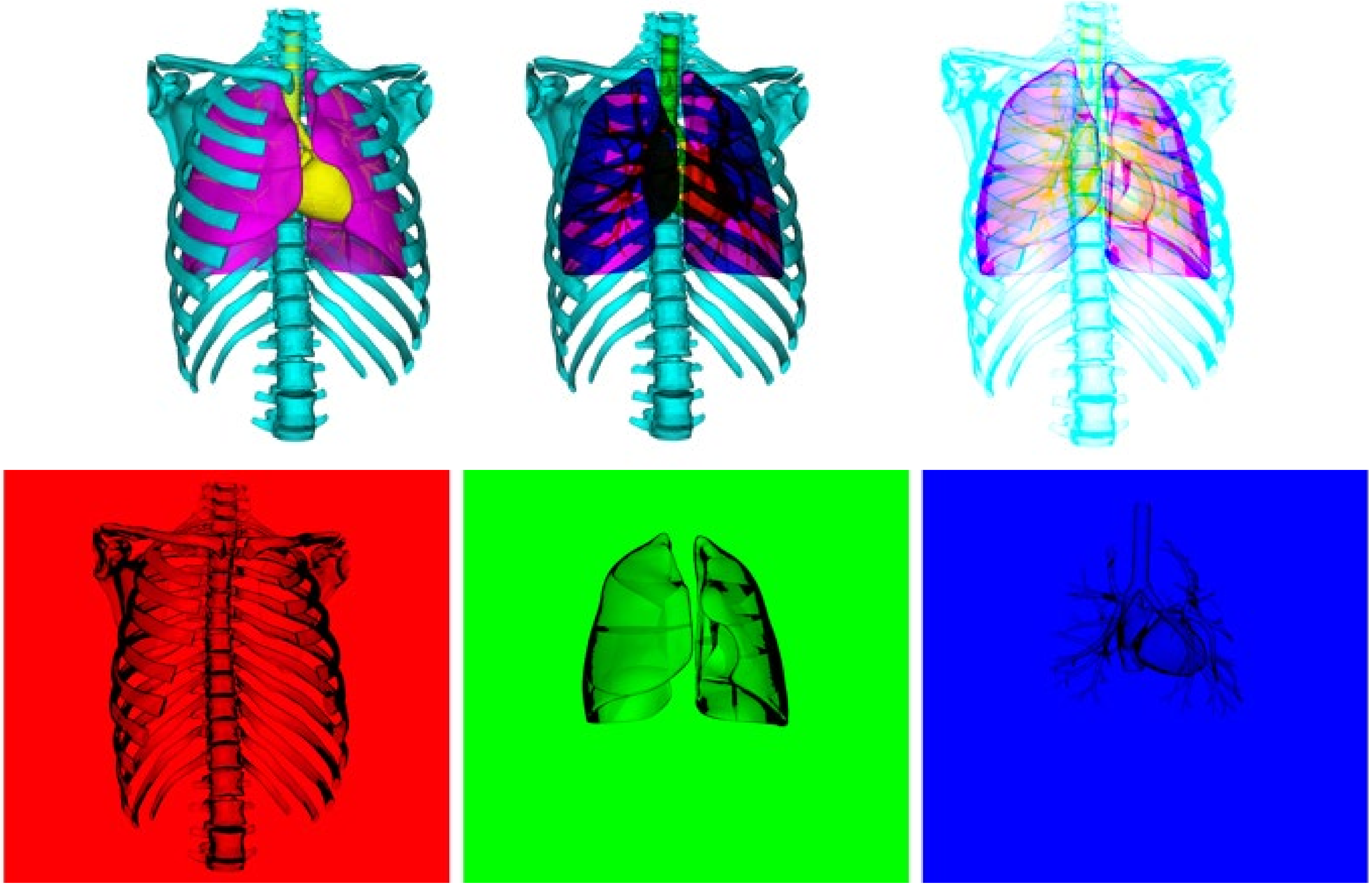


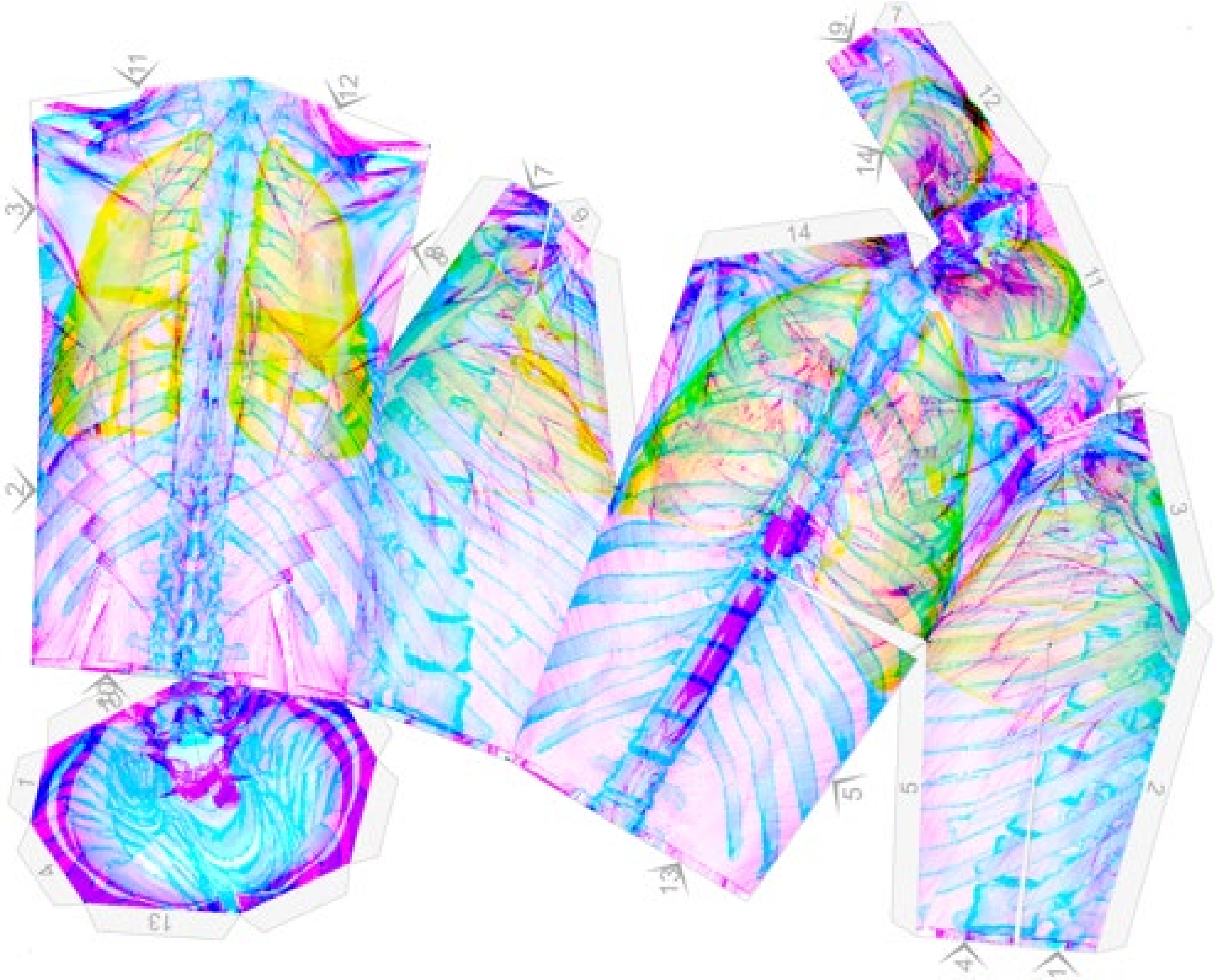
2nd Concept: Papercrafts

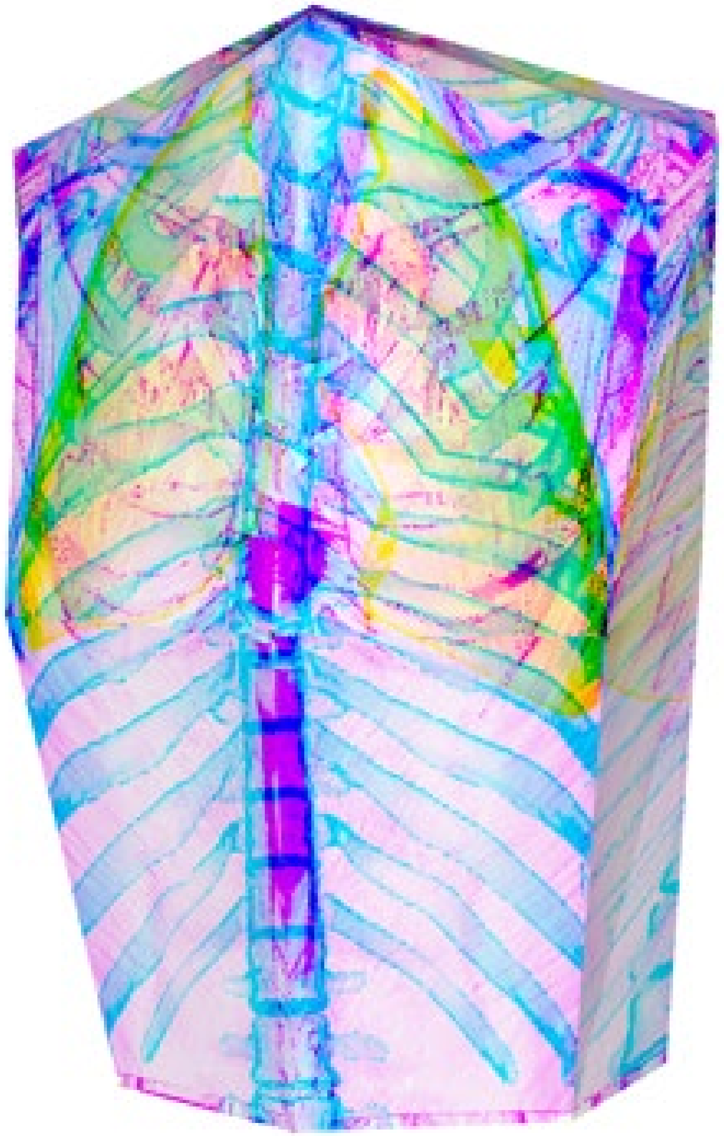
Benefits

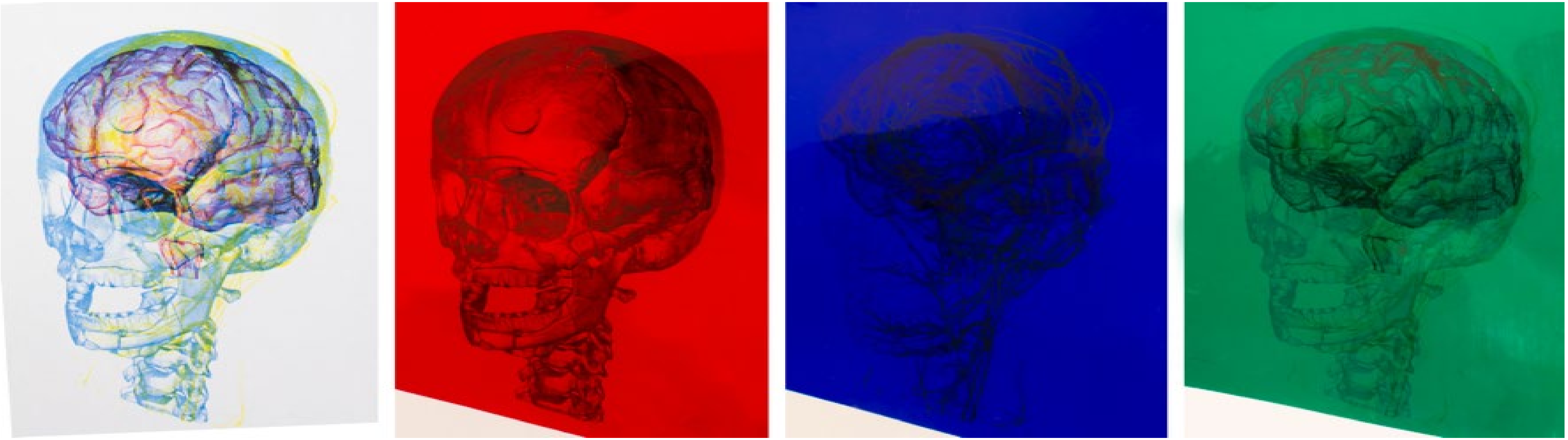


Raw Data
Processed Data
Digital Visualization
Visual Presentation
Physicalization
Data Transformation
Visual Mapping
Presentation Mapping
Rendering





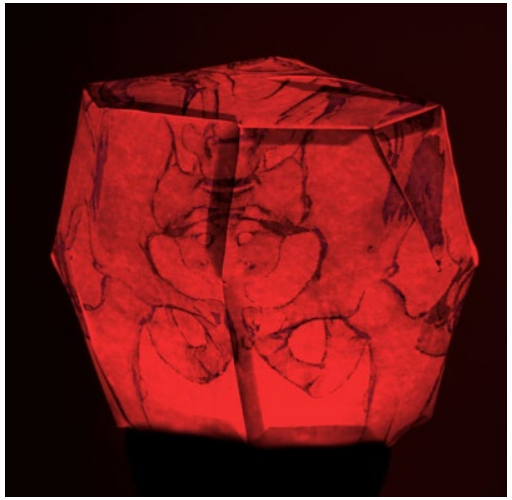


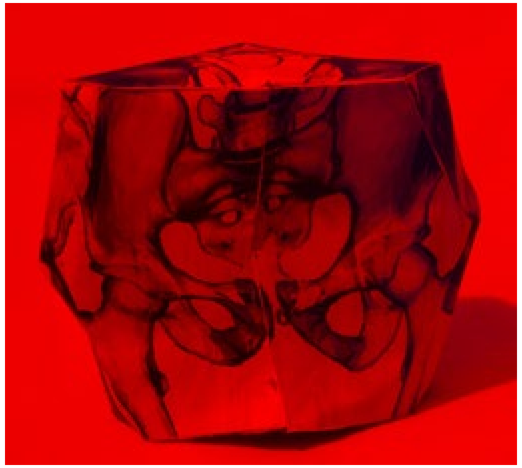


2D with foils

3D with lights

internal light





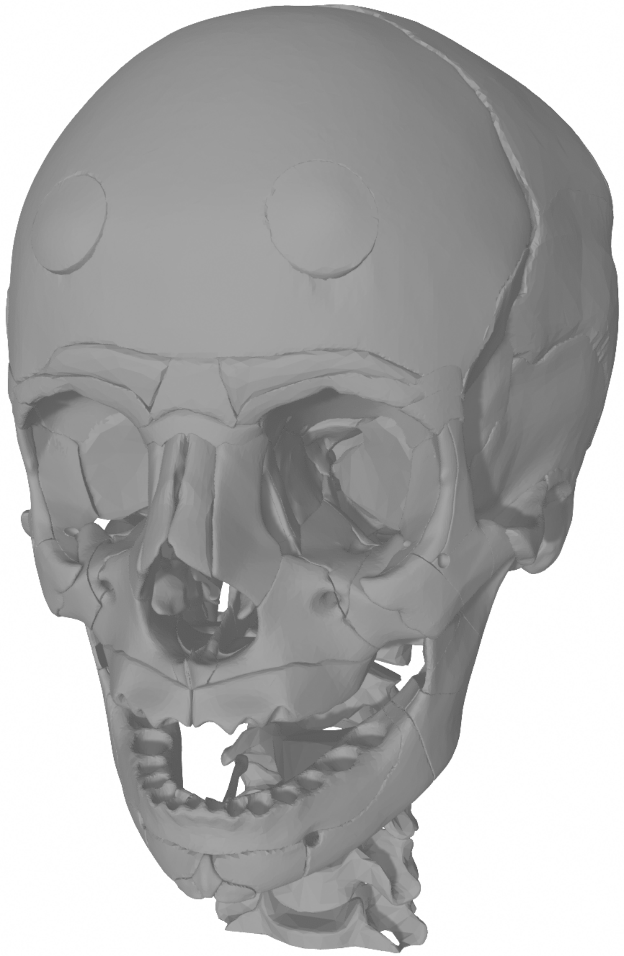
external light

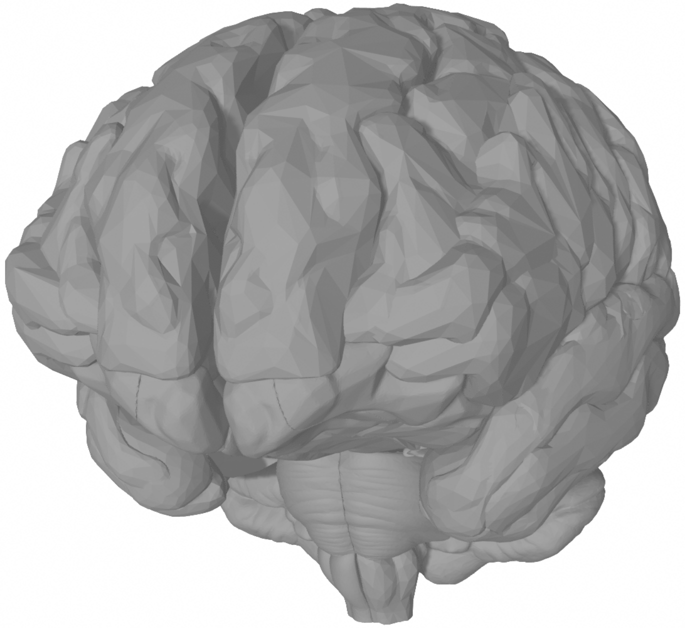
Nested Papercrafts for Anatomical and Biological Edutainment

Marwin Schindler, Thorsten Korpitsch, Renata G. Raidou, and Hsiang-Yun Wu

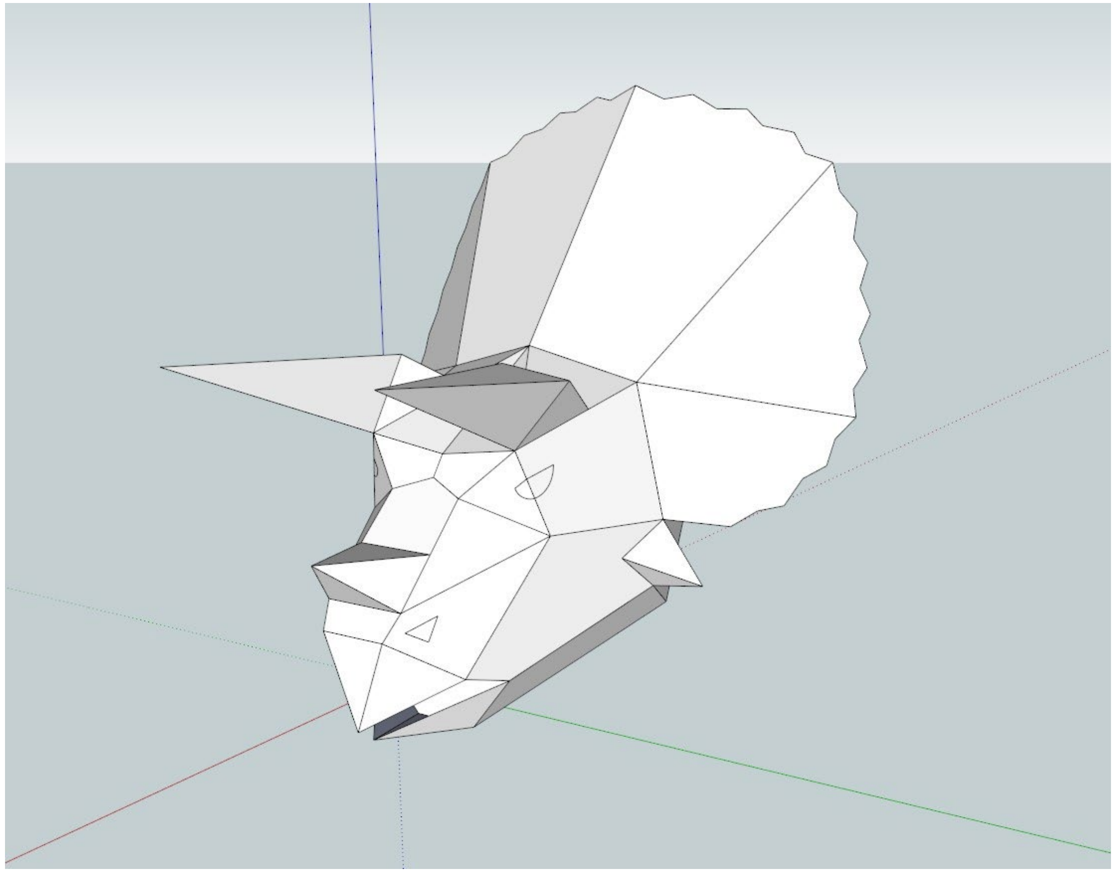
EUROVIS 2022 ROME

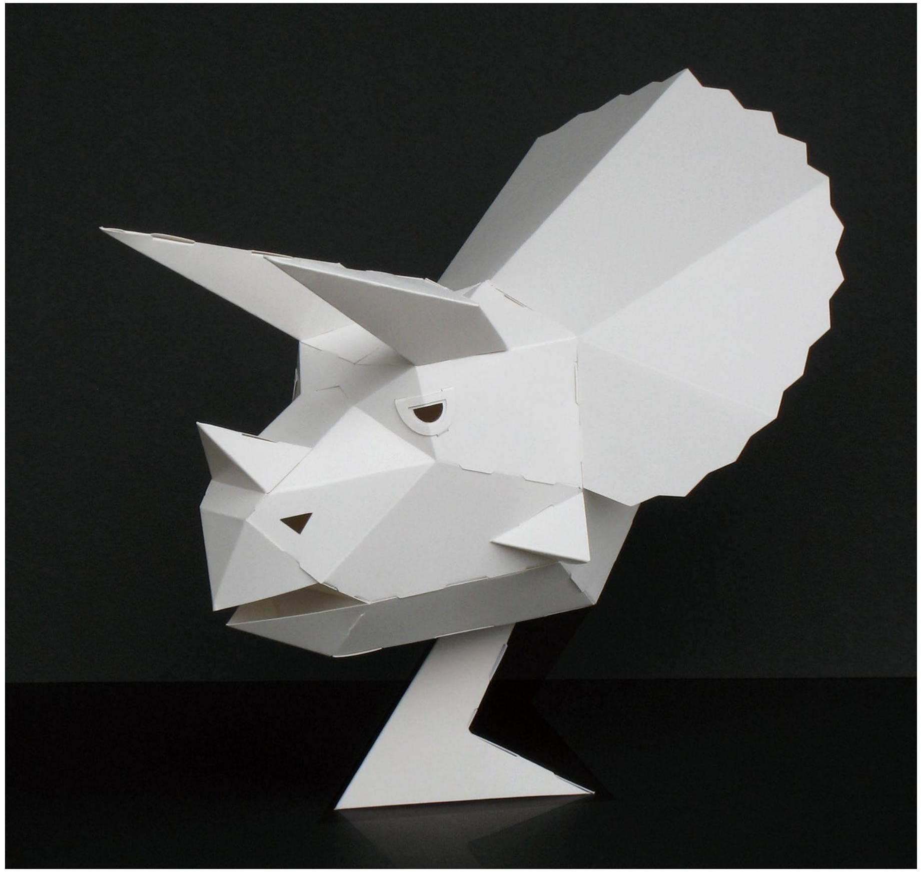
Nested Papercrafts





Motivation

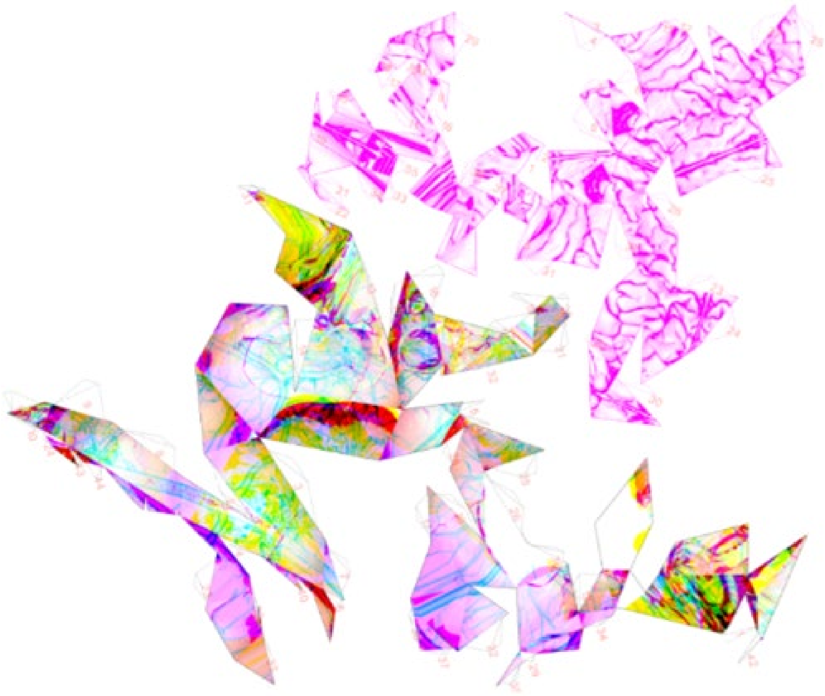




Amao Chan Art Studio https://amaochan.work/a

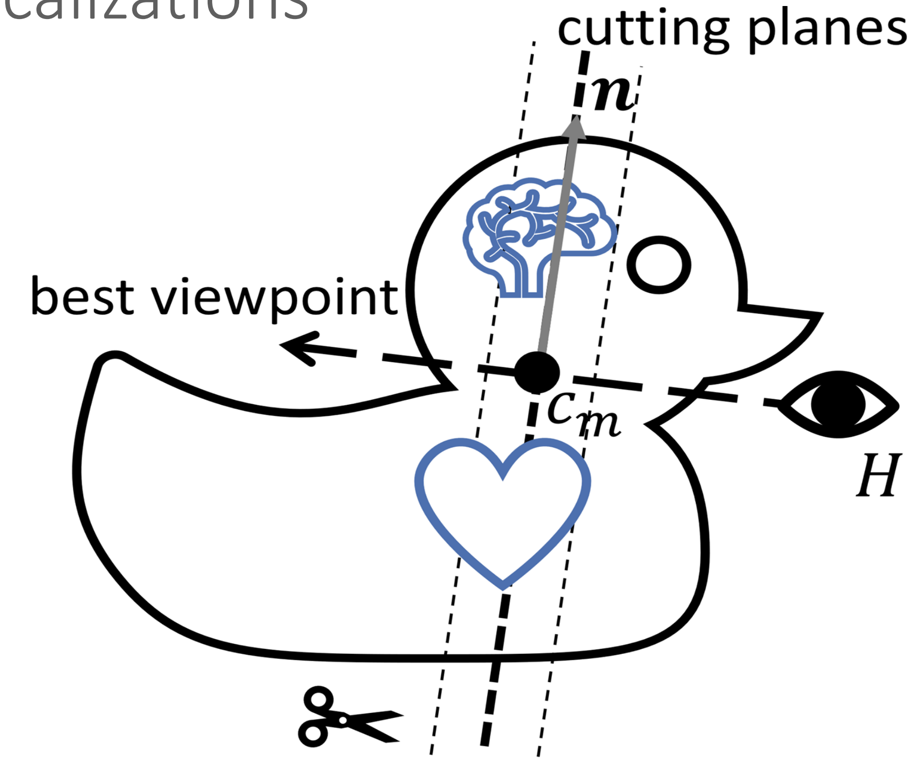
Contribution

- Workflow for Computer-Aided
  Generation of Nested Papercraft Physicalizations



Contribution

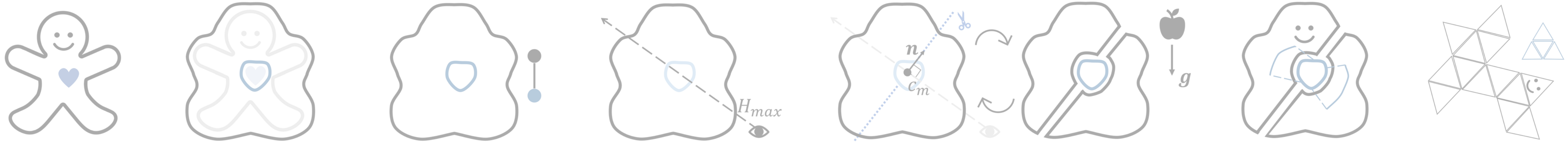
- Workflow for Computer-Aided Generation of Nested Papercraft Physicalizations
- Optimal Visibility of Nested Structures



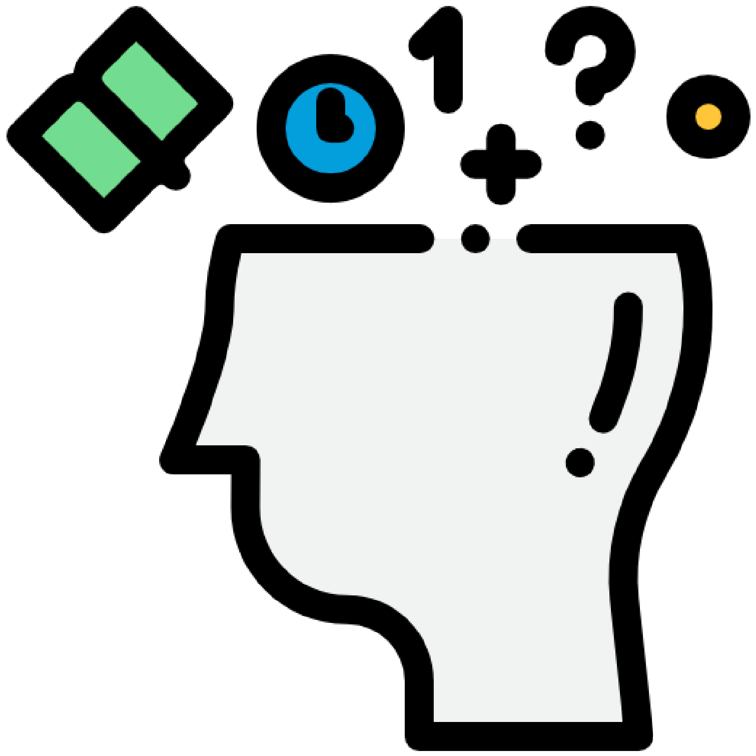
Contribution

- Workflow for Computer-Aided Generation of Nested Papercraft Physicalizations
- Optimal Visibility of Nested Structures
- Strategy for Generating Realizable Papercrafts

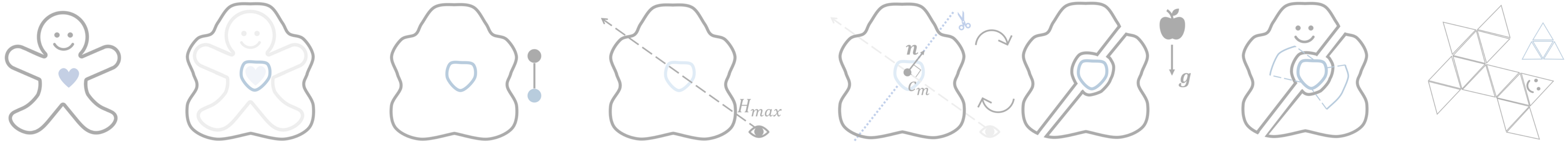
Workflow - Requirements



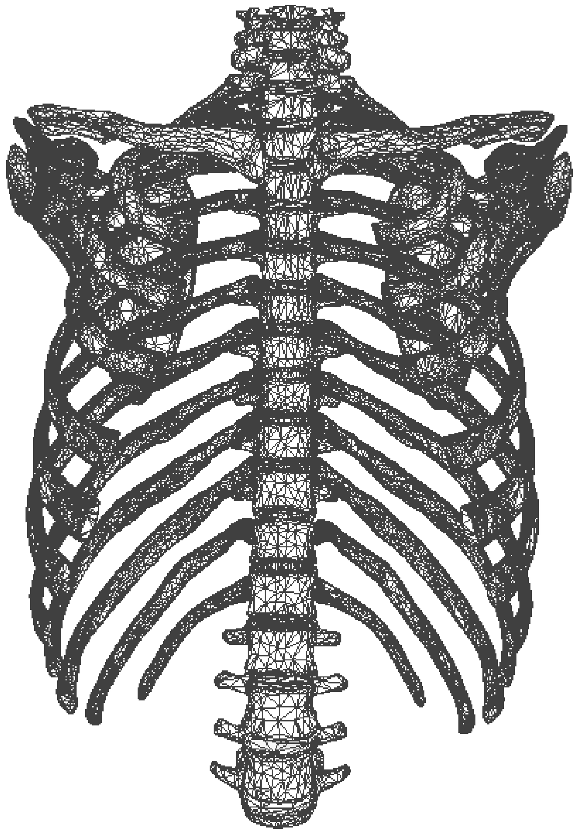
- (R1) No Domain Knowledge



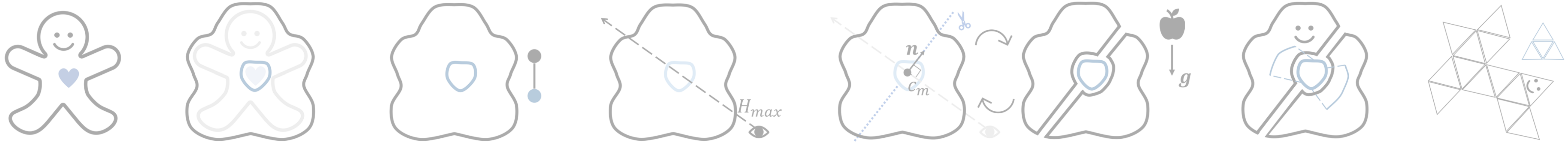
Workflow - Requirements



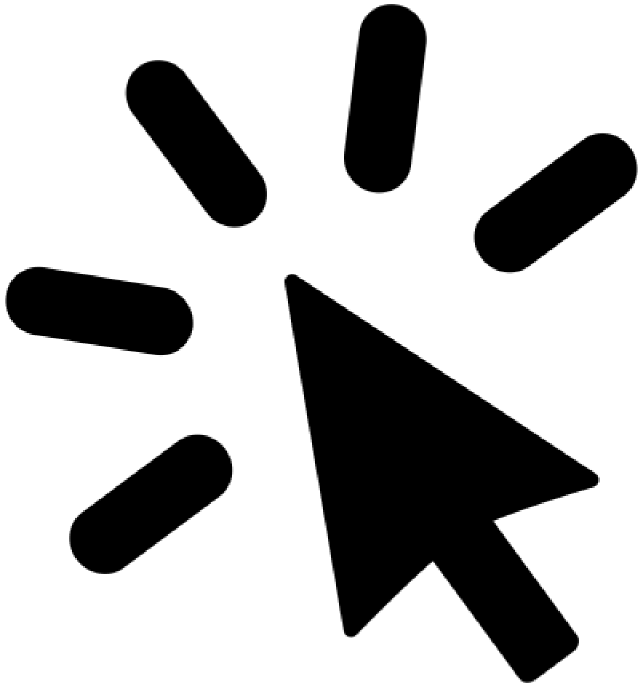
- (R1) No Domain Knowledge
- (R2) 3D Mesh Model Input



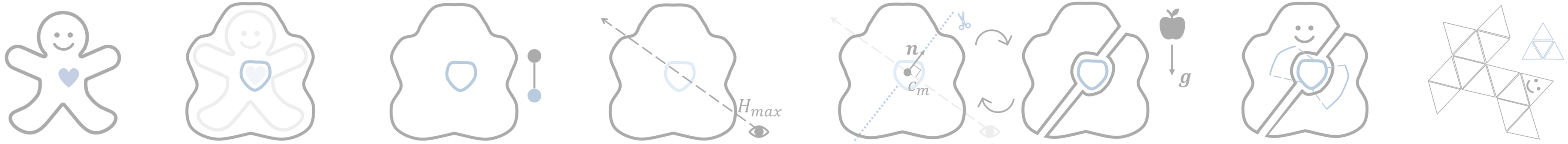
Workflow - Requirements



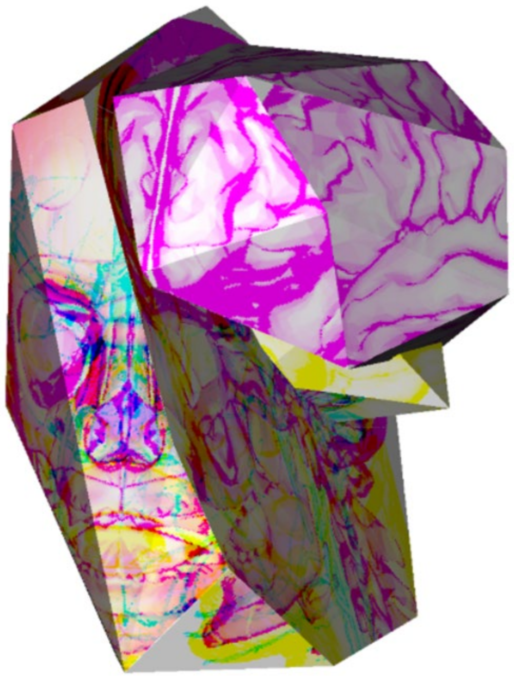
- (R1) No Domain Knowledge
- (R2) 3D Mesh Model Input
- (R3) No Complex User Interaction



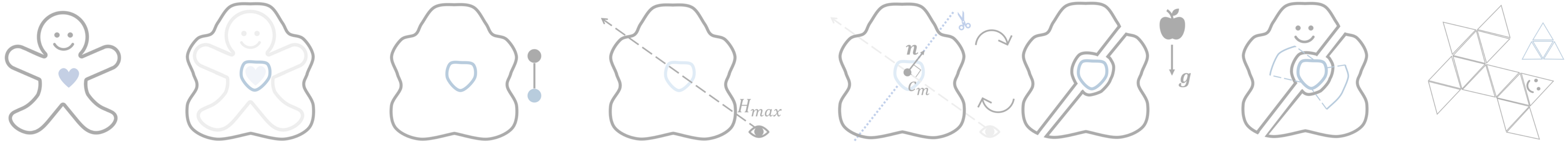
Workflow - Requirements



- (R1) No Domain Knowledge
- (R2) 3D Mesh Model Input
- (R3) No Complex User Interaction
- (R4) Easy-to-Assemble Engaging Physical Twin

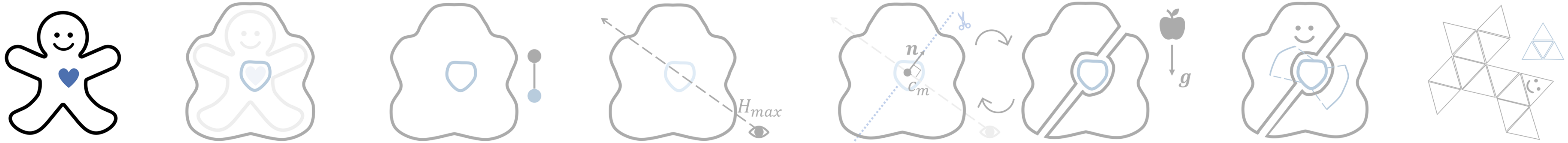


Workflow - Requirements

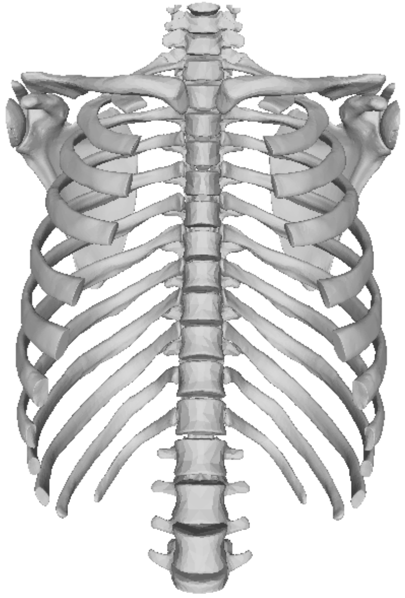


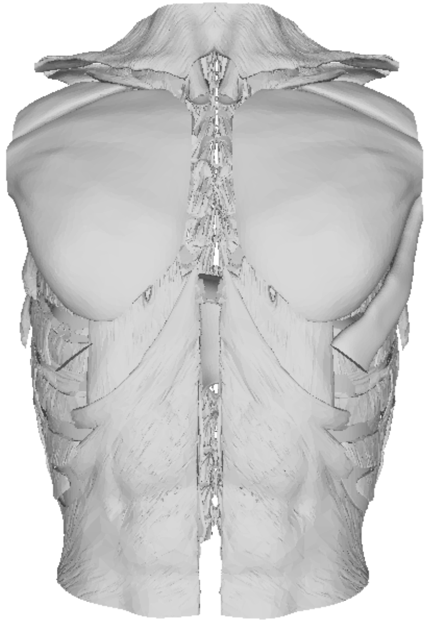
- (R1) No Domain Knowledge
- (R2) 3D Mesh Model Input
- (R3) No Complex User Interaction
- (R4) Easy-to-Assemble Engaging Physical Twin
- (R5) Affordable and Available Resources

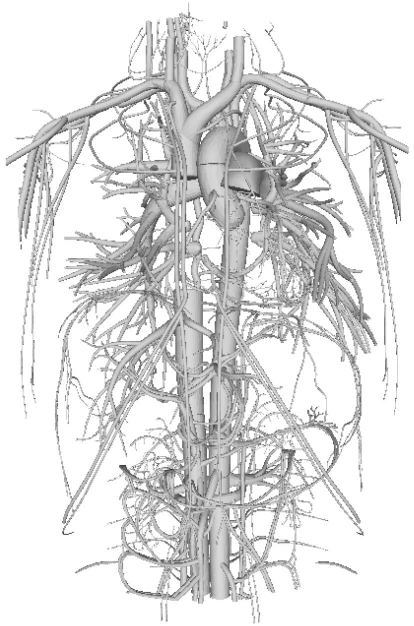
Workflow - Input



- Registered Meshes from Anatomical and Biological Models

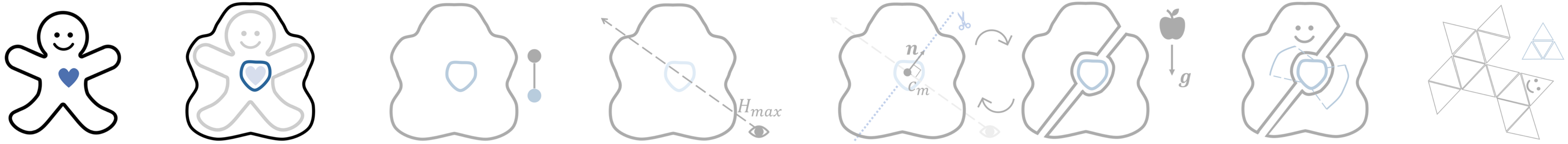




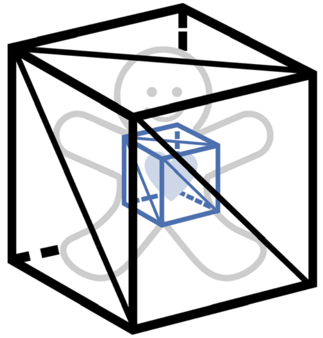


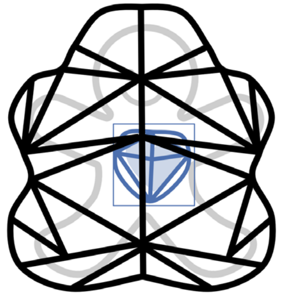
BodyParts3D: 3D Structure Database for Anatomical Concepts, Mitsuhashi et al., 2009.

Workflow - Approximation

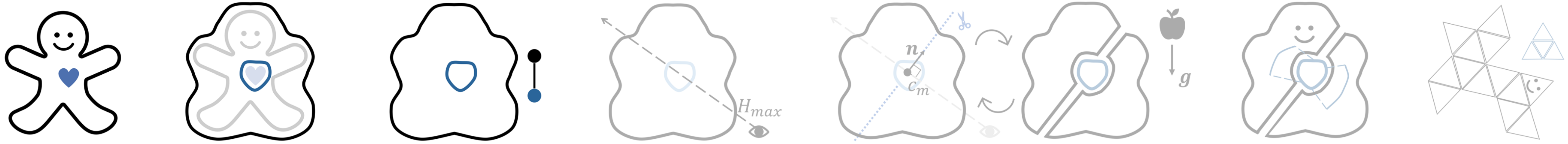


- Feasibility of Reconstruction
- Limit Complexity
- Approximation by Subdivision of Bounding Box (BBox)
    - Calculate BBox
    - Subdivide BBox
    - Move Vertices to Closest Point on Surface

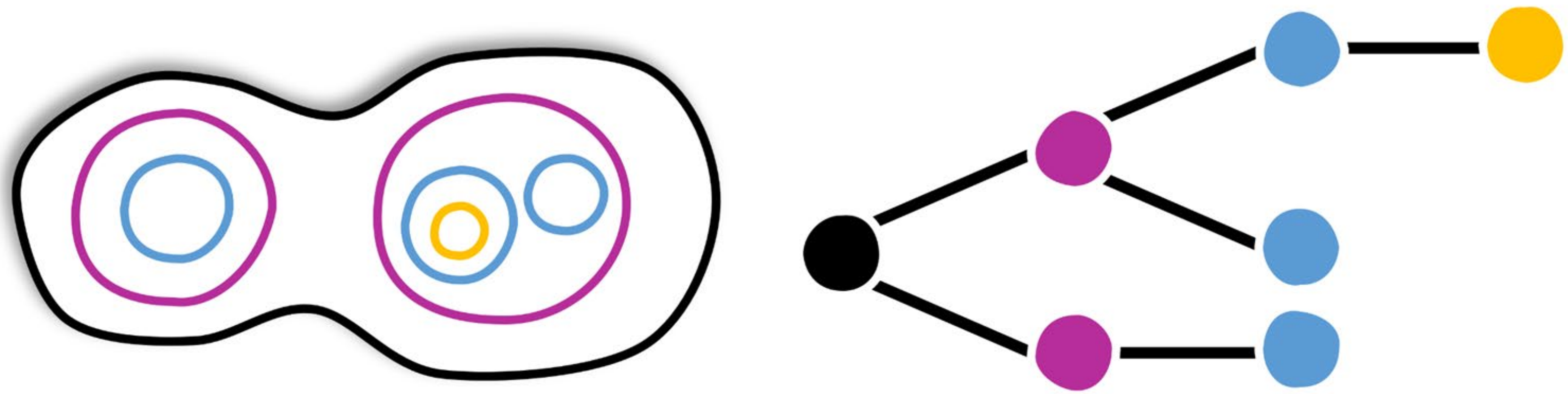




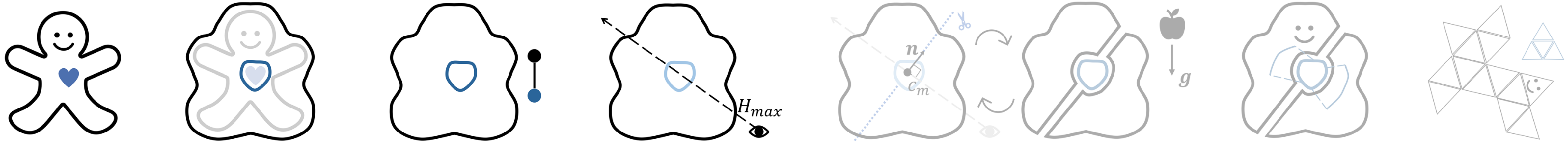
Workflow - Hierarchy



- Calculate Hierarchy Using Approximated Input
  - Check if All Vertices of Mesh A are Inside Mesh B
  - 3D Iso-oriented Box Intersection Tests on Edges



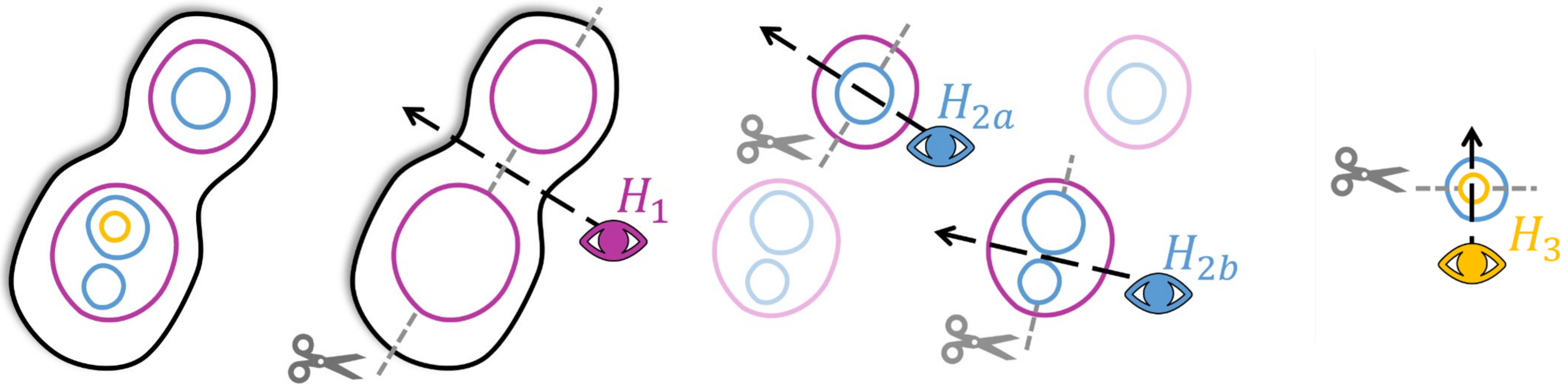
Workflow - Viewpoint



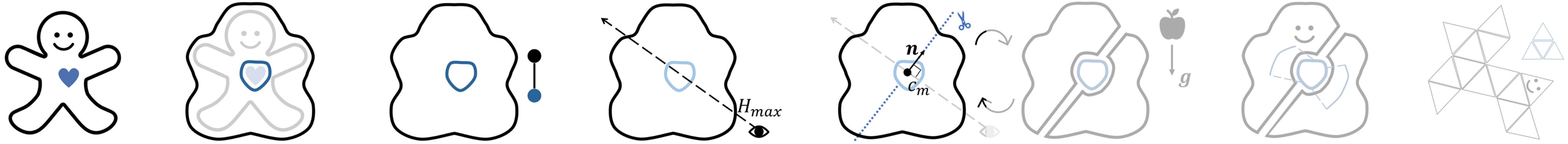
- Provide Optimal Viewpoint on Inner Levels
- Maximum Viewpoint Entropy

Viewpoint Selection Using Viewpoint Entropy, Vazquez et al., 2001.

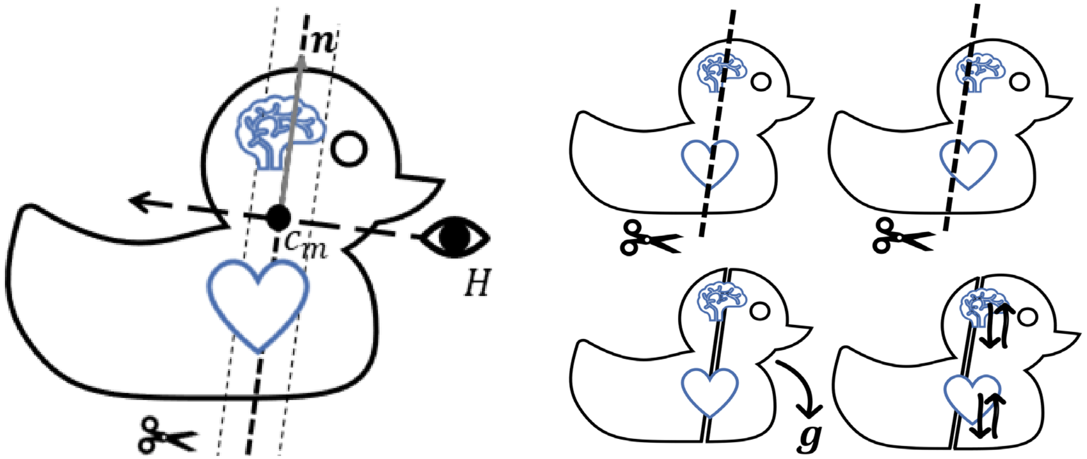
$$H_l = \sum_{i=0}^{N_l} \frac{A_{i,l}}{A_t} log \frac{A_{i,l}}{A_t}$$



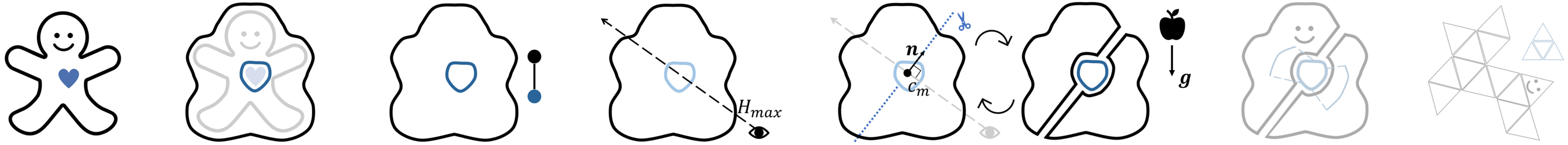
Workflow - Cutting



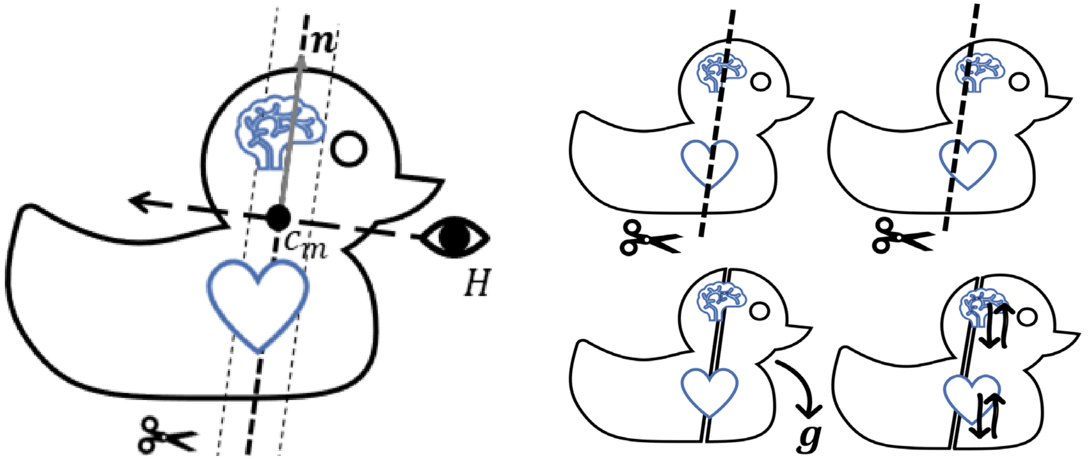
- Subtract Inner Mesh
- Cut Each Level Using the Optimal Viewpoint



Workflow - Stability

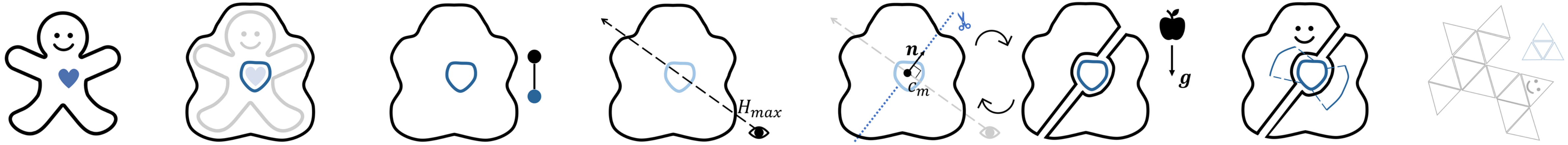


- Subtract Inner Mesh
- Cut Each Level Using the Optimal Viewpoint
- Ensure a Feasible and Stable Result

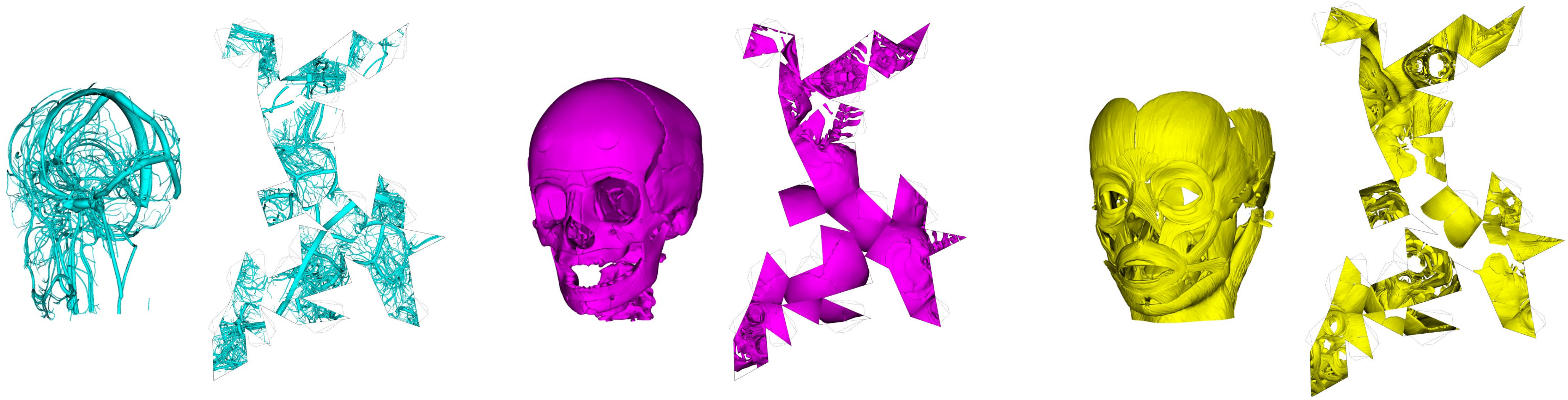


Forward Dynamics - The Articulated-Body Method. Featherstone, 1987.

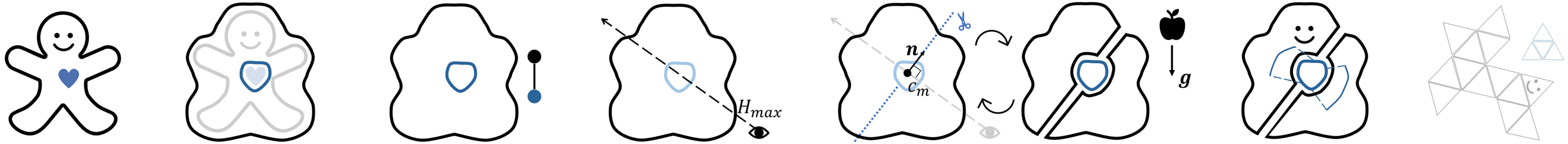
Workflow - Projection



- Create a Texture for Each Anatomical Structure



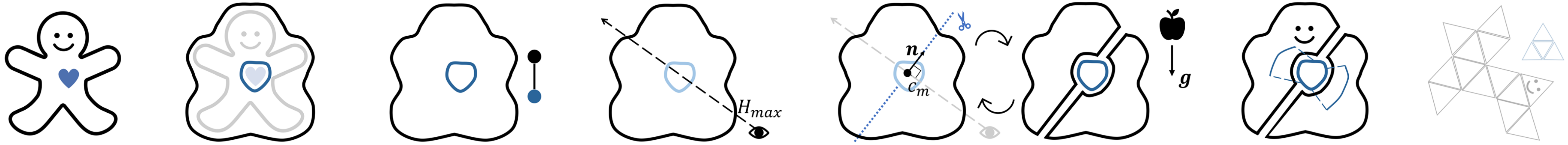
Workflow - Projection



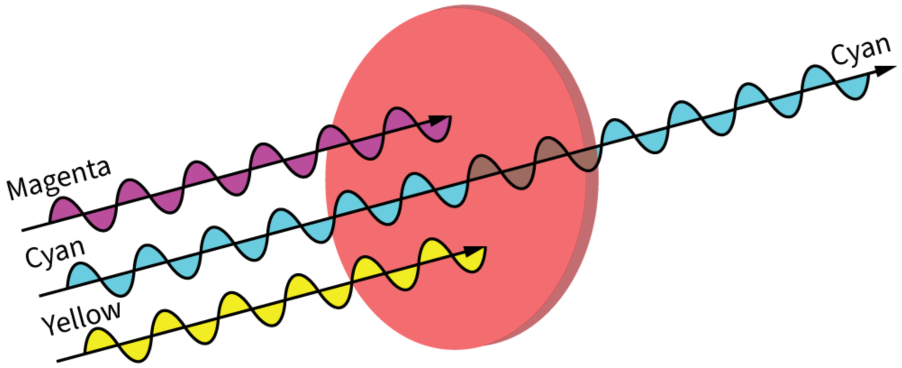
- Create a Texture for Each Anatomical Structure
  - Inflate Inner Parts
  - Clip Distant Features
  - Project on BBox

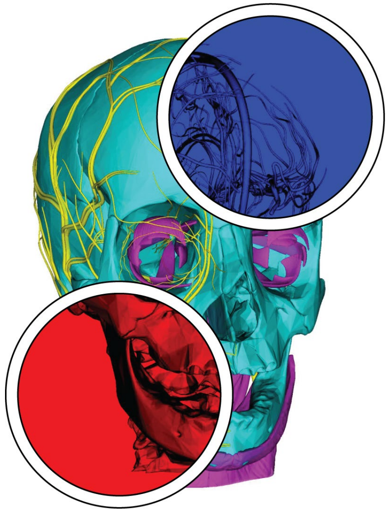
Inflation Clipping BBox

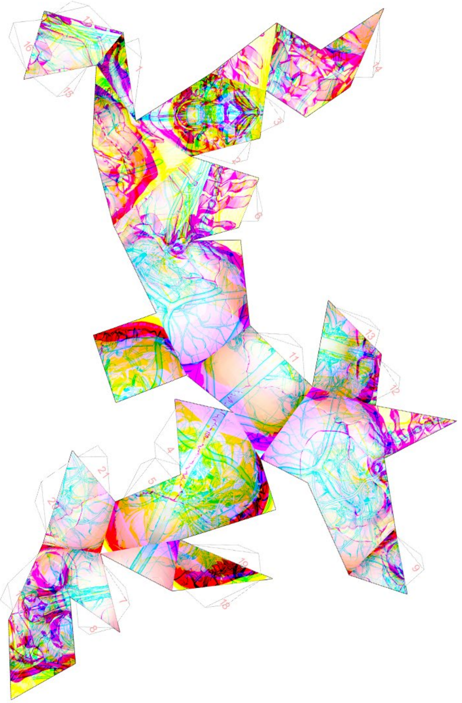
Workflow - Projection



- Create a Texture for Each Anatomical Structure
- Blend Textures for Each Level

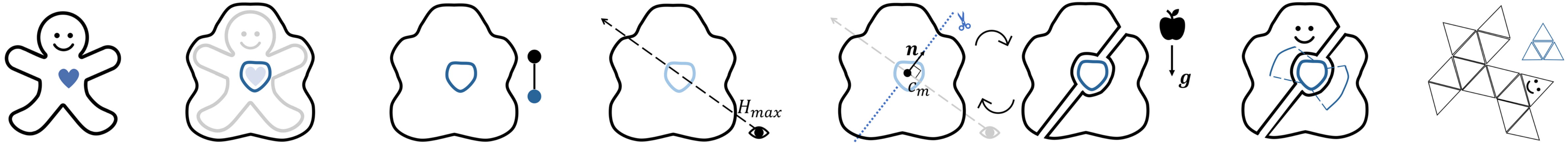




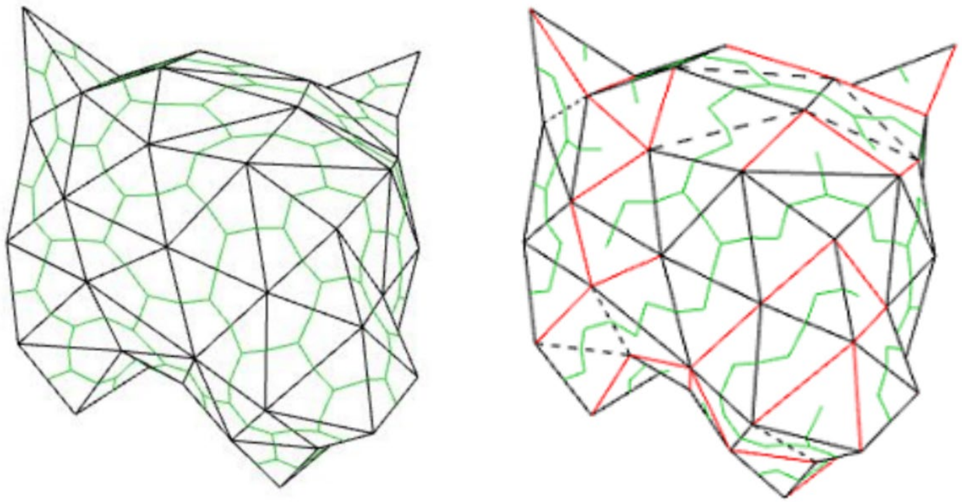


The Anatomical Edutainer, Schindler et al., 2020.

Workflow - Unfolding

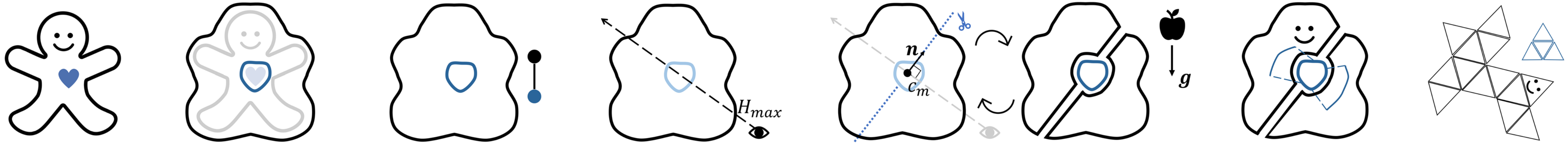


- Calculate Dual Graph
- Calculate Minimum Spanning Tree

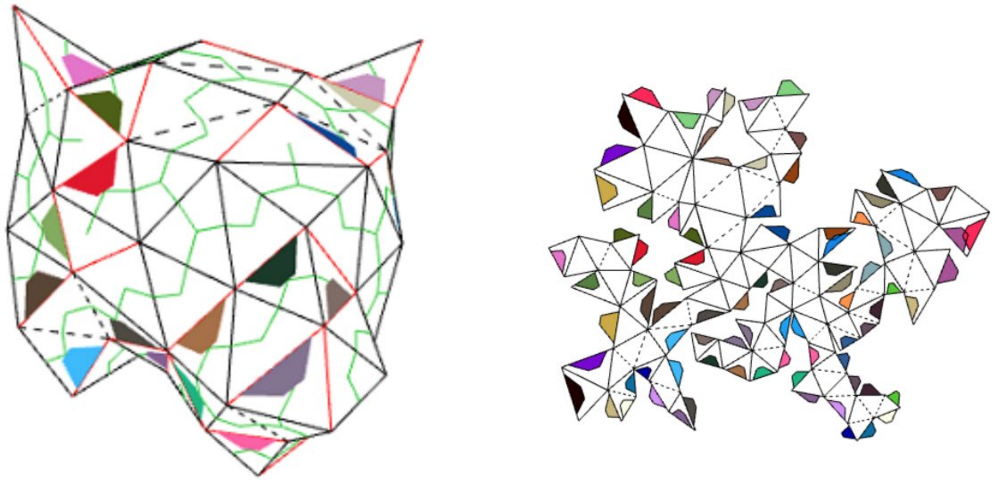


Simulated Annealing to Unfold 3D Meshes and Assign Glue Tabs, Korpitsch et al., 2020.

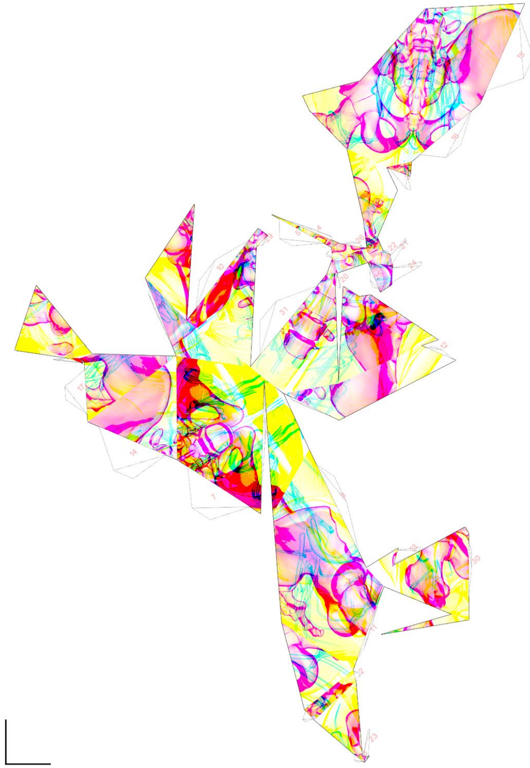
Workflow - Unfolding

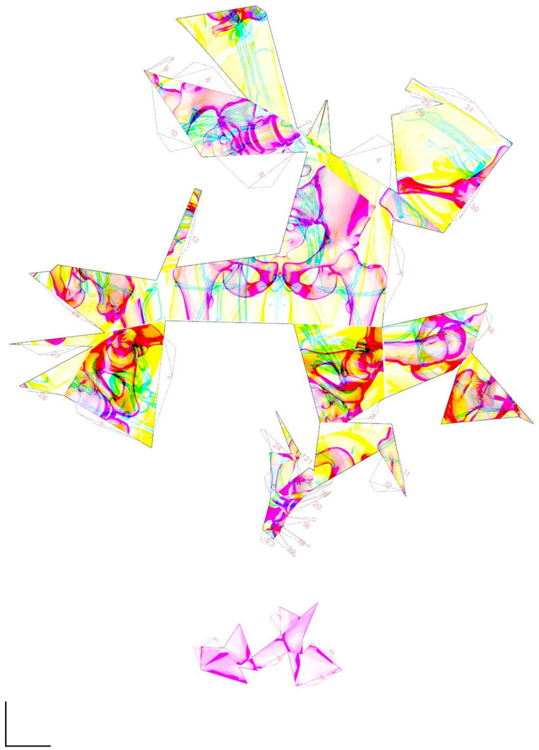


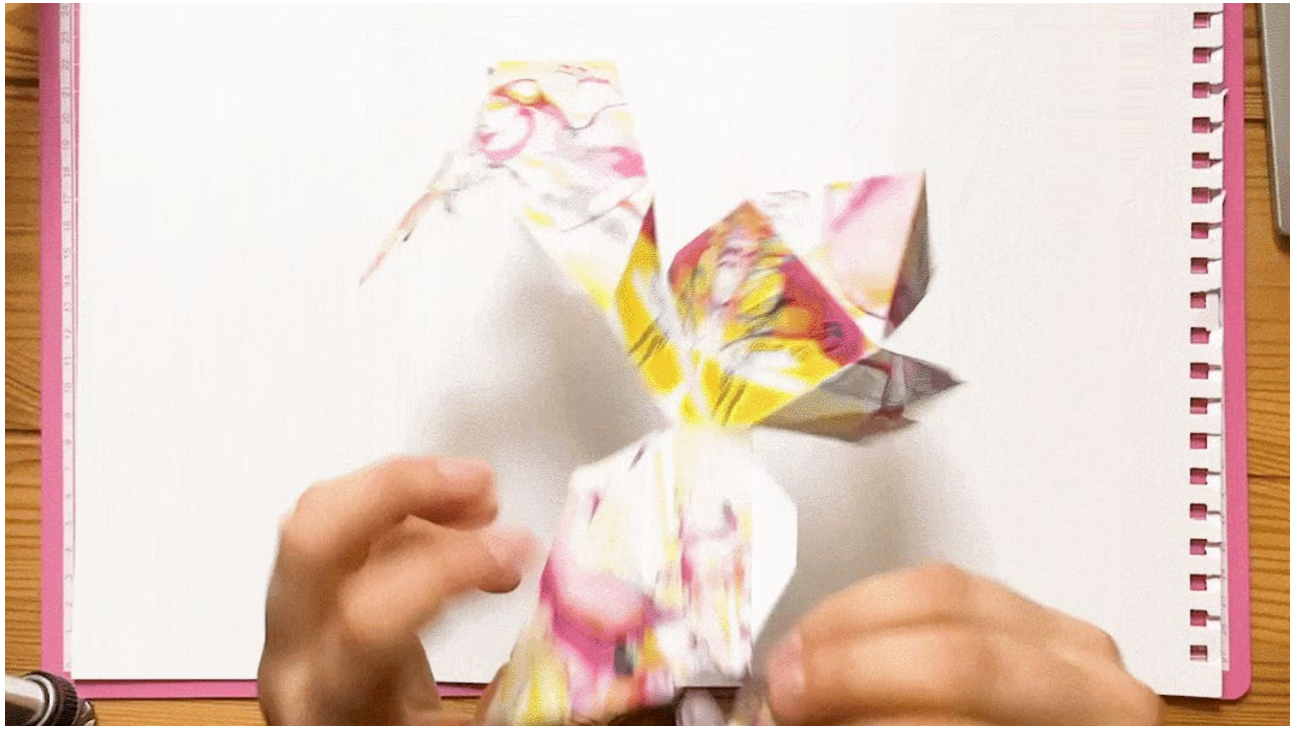
- Calculate Dual Graph
- Calculate Minimum Spanning Tree
- Add Minimum Number of Gluetabs

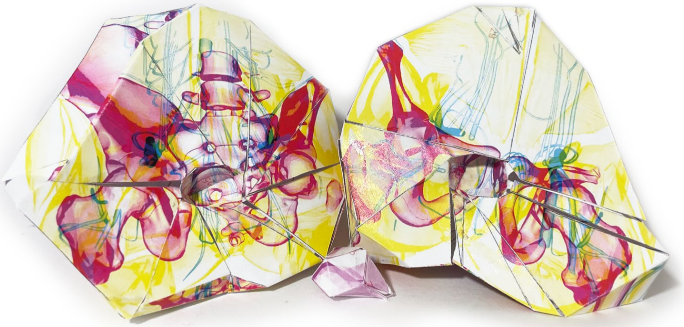


Simulated Annealing to Unfold 3D Meshes and Assign Glue Tabs, Korpitsch et al., 2020.

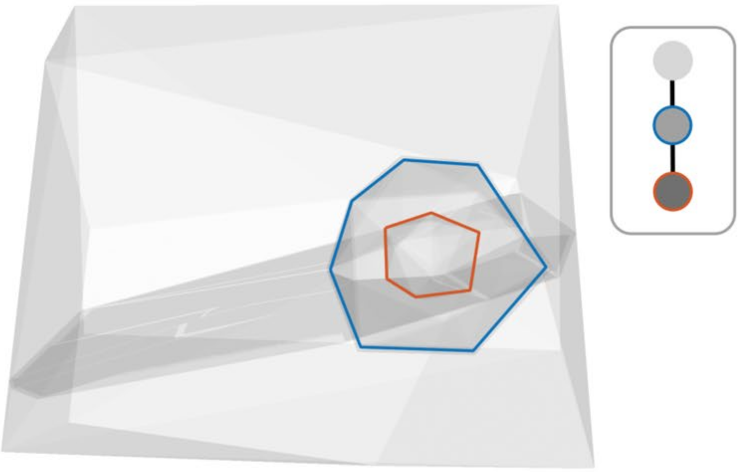


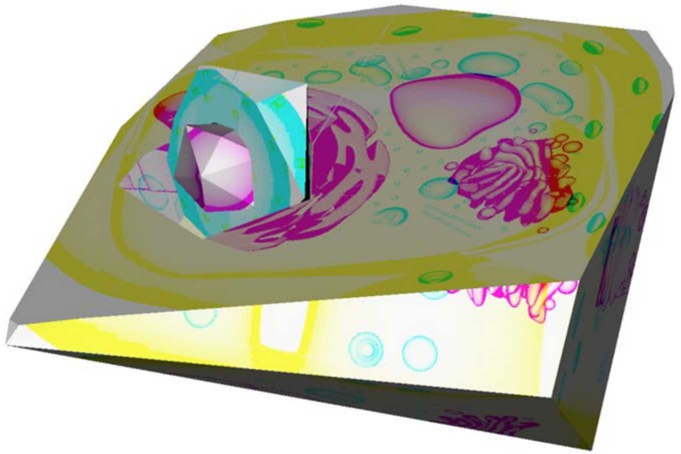




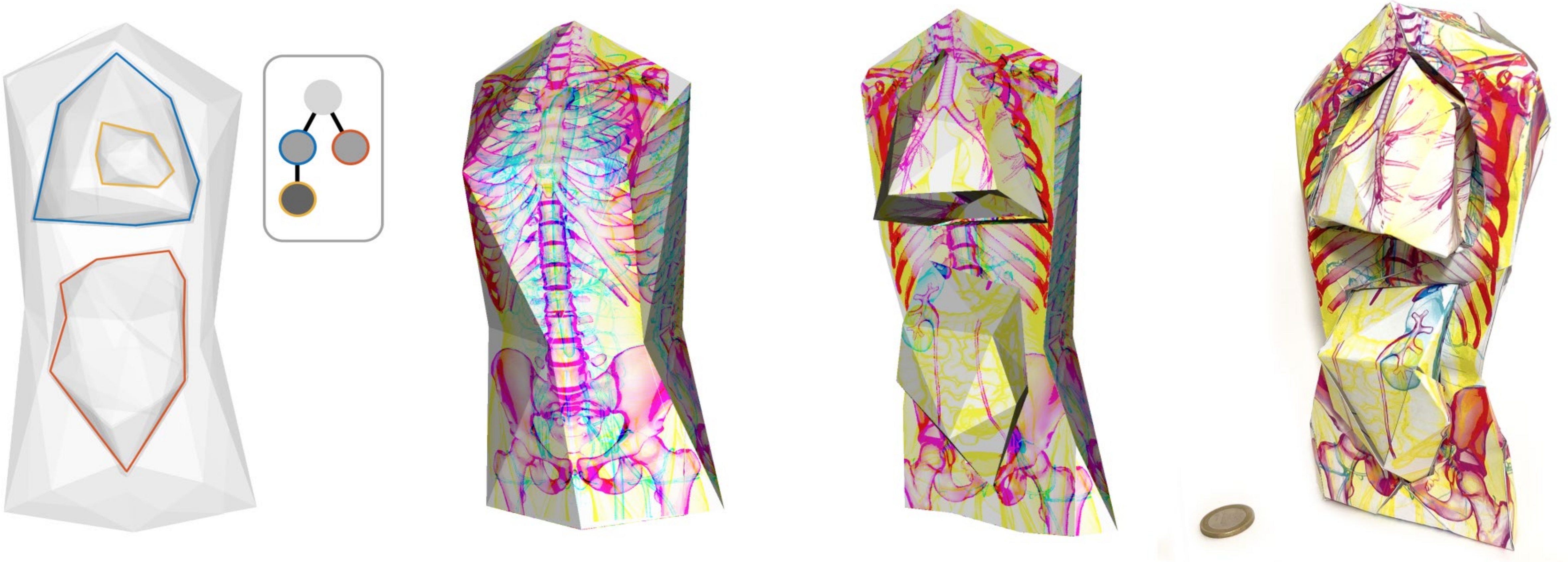


Results: Plant Cell





Results: Human Anatomy



Evaluation

User	1 (M)	2 (M)	3 (F)	4 (F)	5 (F)	6 (M)	7 (M)	8 (M)	9 (M)	10 (M)	avg ± sd
Time A (mm:ss)	99:38	95:04	112:32	99:12	59:04	53:02	98:04	103:07	117:04	67:32	90:26 ± 22:23
Time B (mm:ss)	85:52	92:21	99:56	89:33	48:52	40:06	86:23	N/A	N/A	N/A	77:35 ± 23:13

- Initial User Study with 10 Participants
- Constructing the Head Model

Evaluation

User	1 (M)	2 (M)	3 (F)	4 (F)	5 (F)	6 (M)	7 (M)	8 (M)	9 (M)	10 (M)	avg $\pm$ sd
Time A (mm:ss)	99:38	95:04	112:32	99:12	59:04	53:02	98:04	103:07	117:04	67:32	90:26 $\pm$ 22:23
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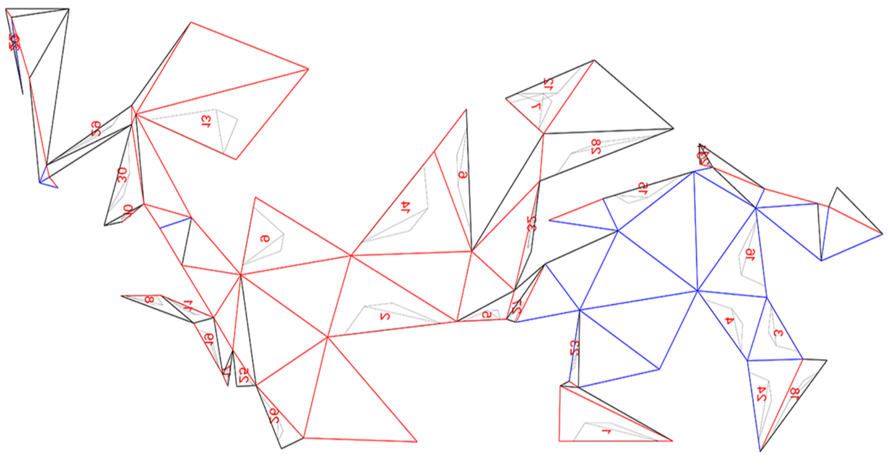
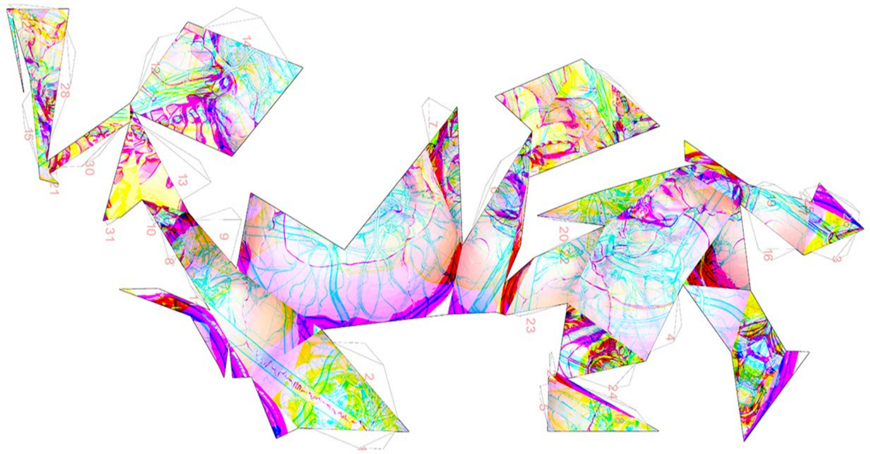
- Initial User Study with 10 Participants
- Constructing the Head Model
- Additional Indicators for Mountain/ Valley Folds





Evaluation

User	1 (M)	2 (M)	3 (F)	4 (F)	5 (F)	6 (M)	7 (M)	8 (M)	9 (M)	10 (M)	avg ± sd
Time A (mm:ss)	99:38	95:04	112:32	99:12	59:04	53:02	98:04	103:07	117:04	67:32	90:26 ± 22:23
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- Initial User Study with 10 Participants
- Constructing the Head Model
- Additional Indicators for Mountain/ Valley Folds
- New Insights in an Entertaining Way

Evaluation

User	1 (M)	2 (M)	3 (F)	4 (F)	5 (F)	6 (M)	7 (M)	8 (M)	9 (M)	10 (M)	avg ± sd
Time A (mm:ss)	99:38	95:04	112:32	99:12	59:04	53:02	98:04	103:07	117:04	67:32	90:26 ± 22:23
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- Initial User Study with 10 Participants
- Constructing the Head Model
- Additional Indicators for Mountain/ Valley Folds
- New Insights in an Entertaining Way
- Unprofessional in Patient Communication

Evaluation

User	1 (M)	2 (M)	3 (F)	4 (F)	5 (F)	6 (M)	7 (M)	8 (M)	9 (M)	10 (M)	avg ± sd
Time A (mm:ss)	99:38	95:04	112:32	99:12	59:04	53:02	98:04	103:07	117:04	67:32	90:26 ± 22:23
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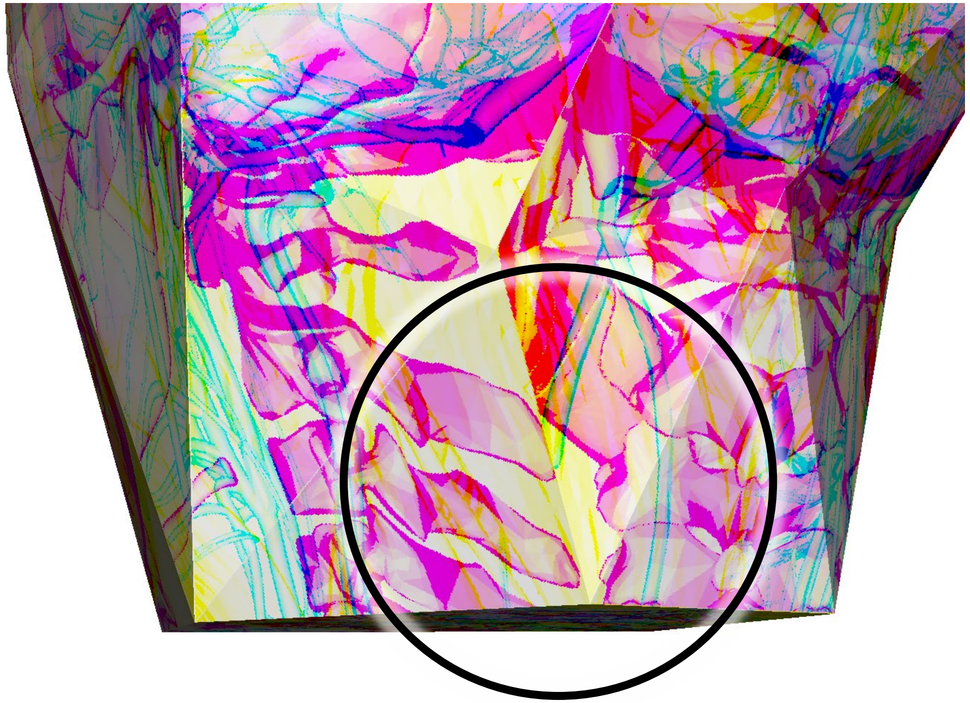
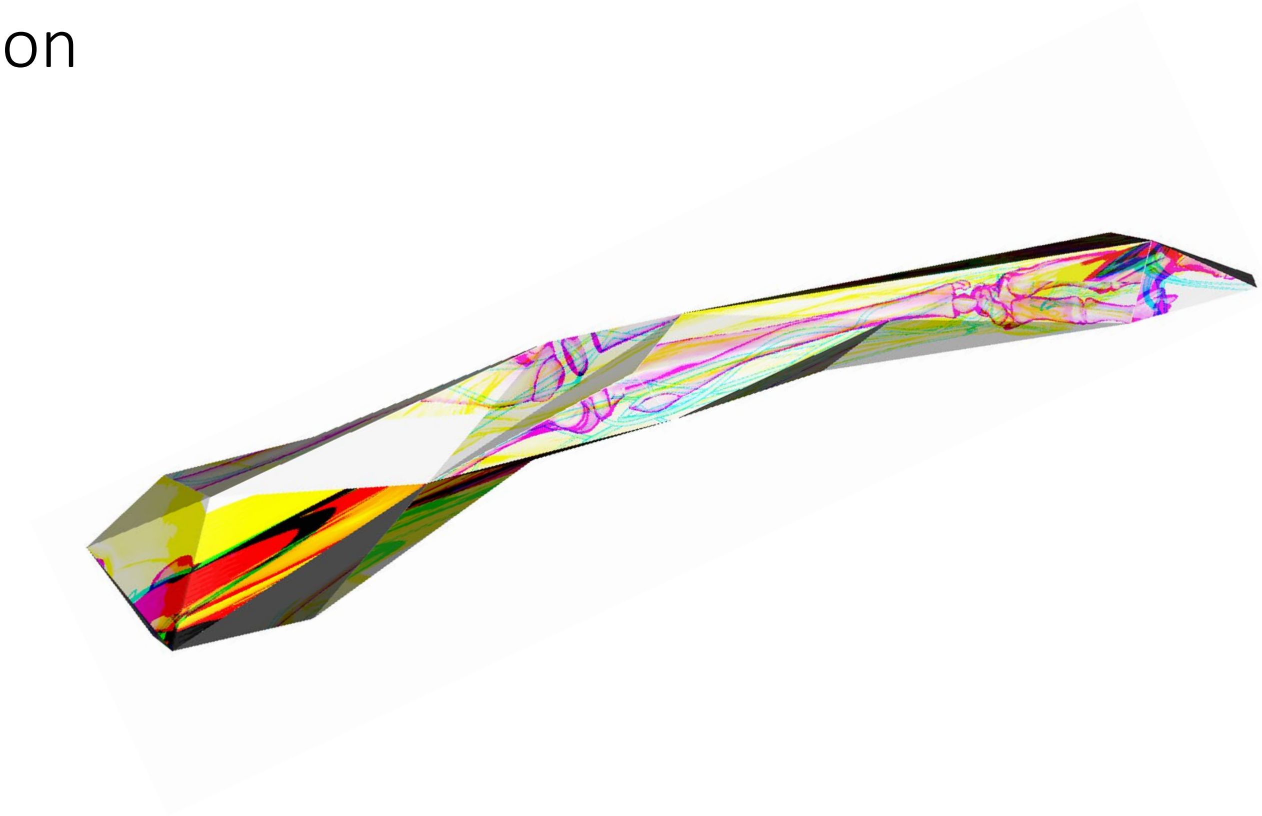
- Initial User Study with 10 Participants
- Constructing the Head Model
- Additional Indicators for Mountain/ Valley Folds
- New Insights in an Entertaining Way
- Unprofessional in Patient Communication
- Children Education

Limitations

Distortions From Mesh Abstraction



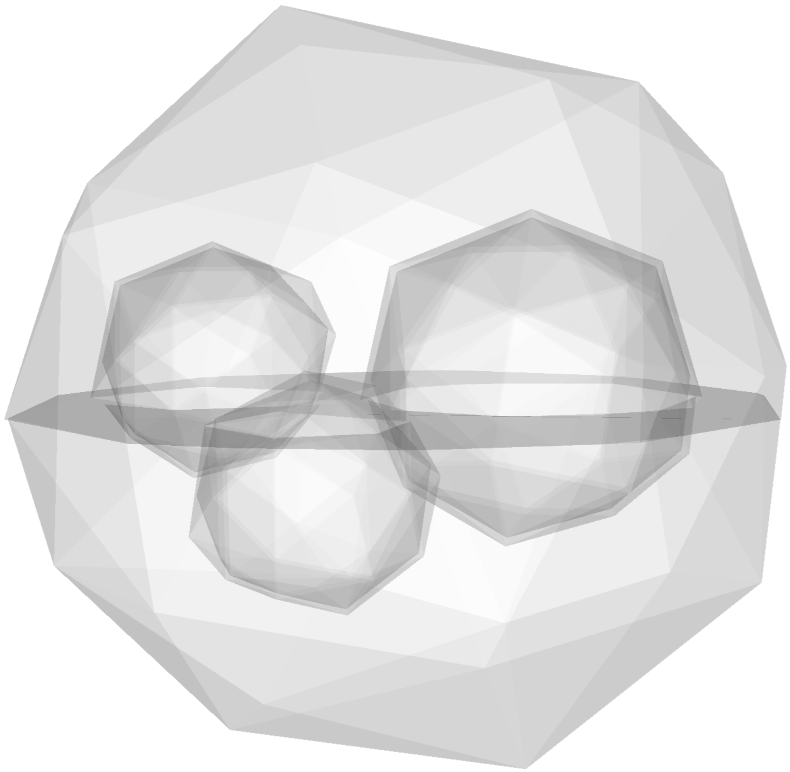


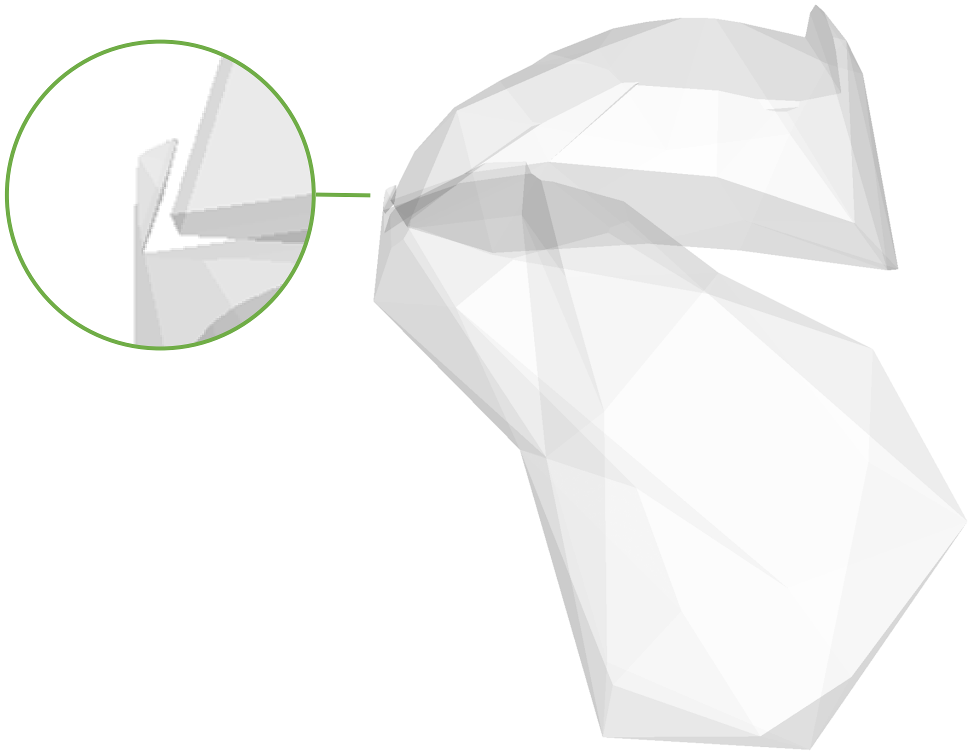
Limitations

Size of inner substructures too small

Limitations

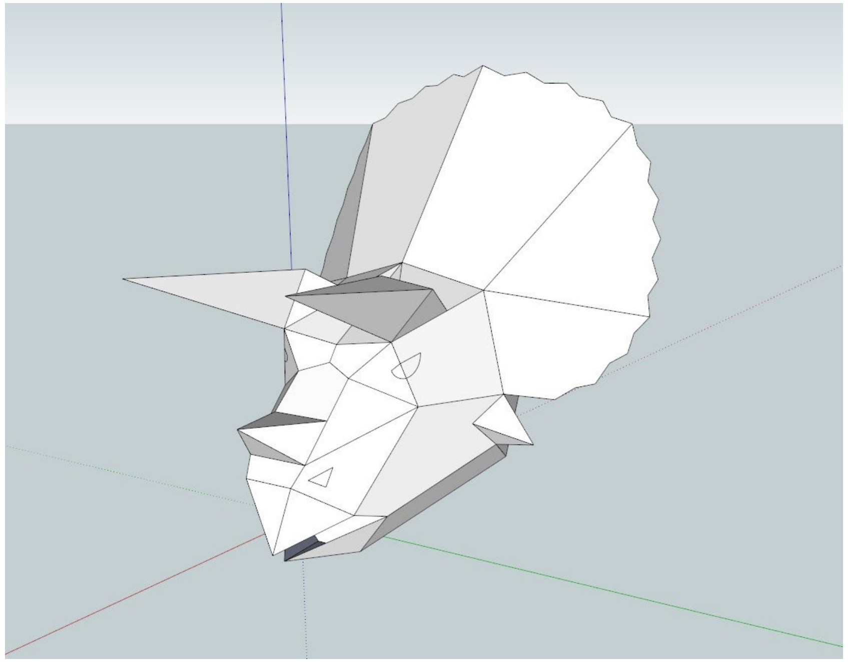
Configuration of Inner Structures





Limitations

Construction Time



Future Work

- Further Domains of Use
- Machine Assisted Construction
- Full-size Papercrafts
- Evaluation of the Entire Fabrication Process

Thank you!

This work would have not been possible without:

Marwin Schindler

Thorsten Korpitsch

Hsiang-Yun Wu

Daniel Pahr

Eduard Gröller