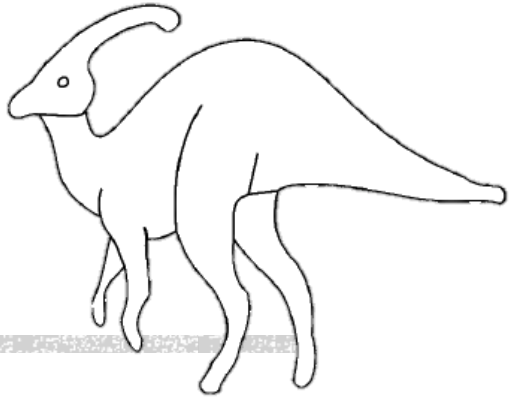
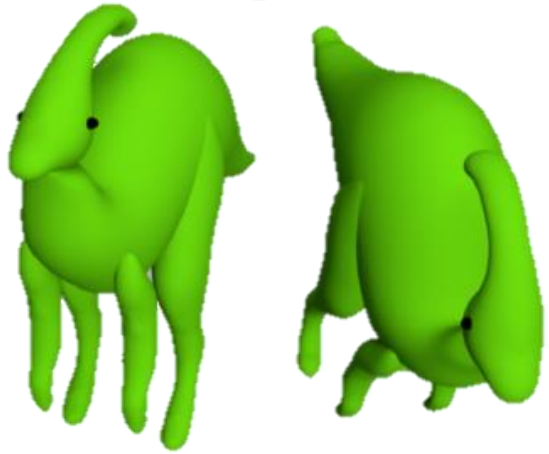
Sketch-based modeling from Single-view drawings and Applications



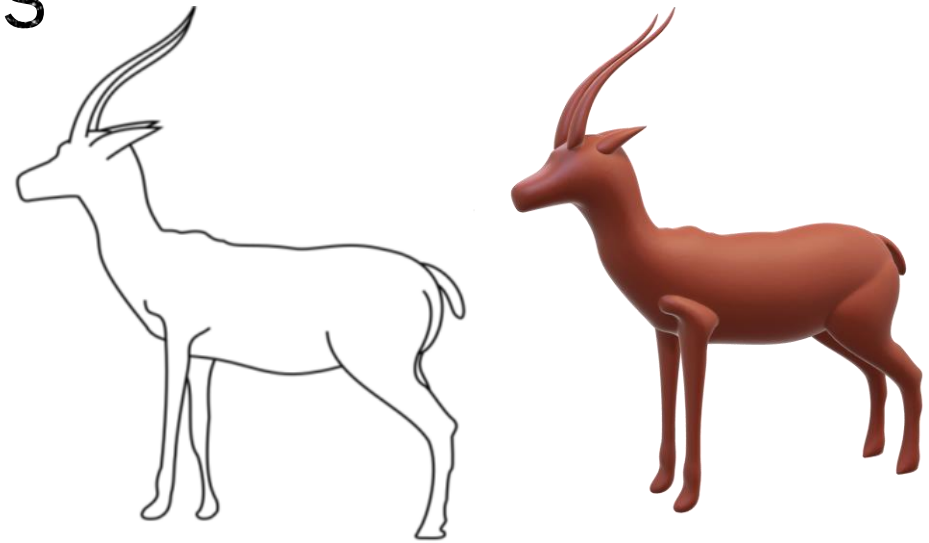
Saulo Ramos de Carvalho Pereira

Mario Costa Sousa João Paulo Gois

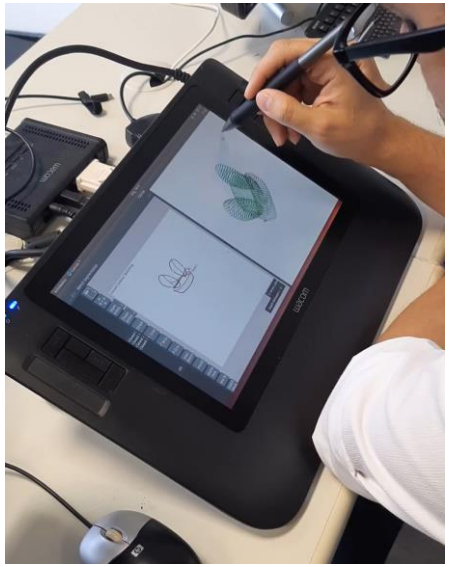


UFABC UNIVERSITY OF CALGARY CAPES

Introduction: About this thesis



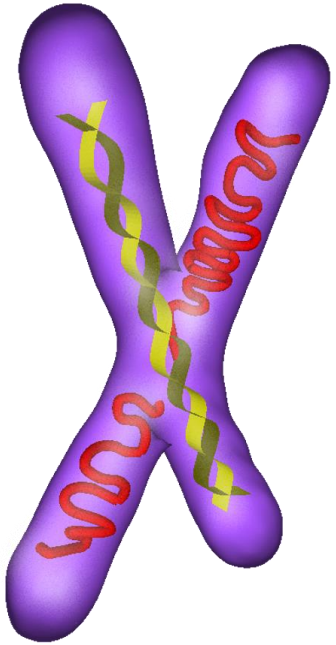
- **Automatic framework**
  - improve the contours in 3D models from 2D input drawings “What you Sketch is What you Get”
  - improve the classification and segmentation of the different parts in the input drawings;

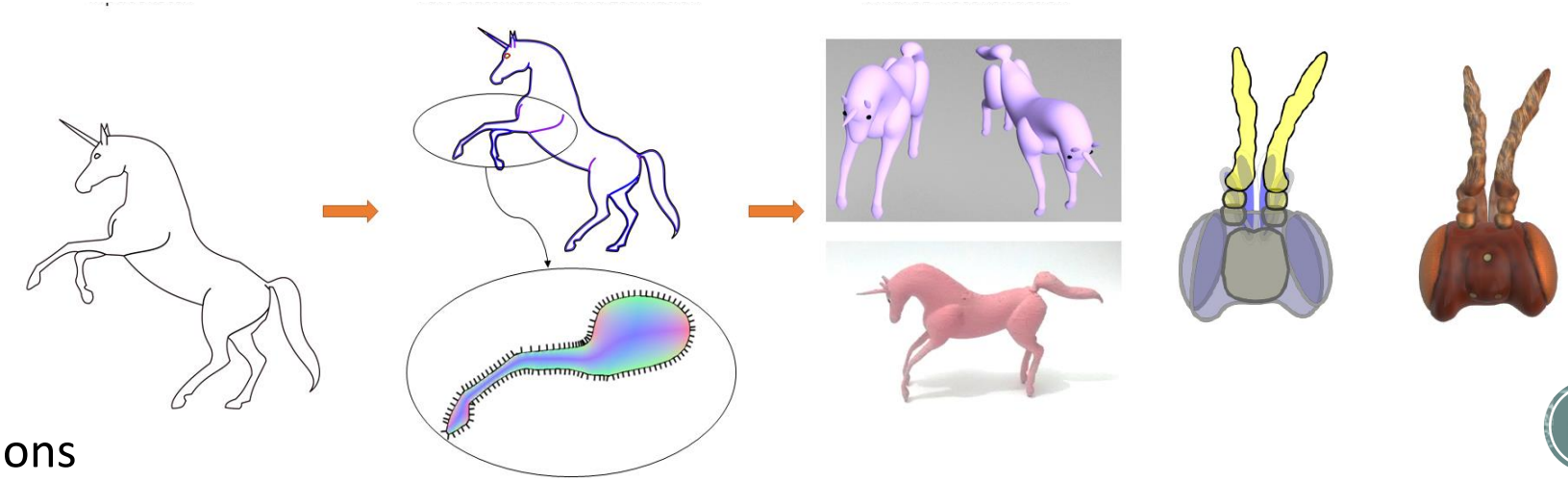


- **Interactive modeling and rendering framework**
  - single-view 2D sketching and 3D modeling
  - inspired by traditional illustration principles and practices
    - ink-line drawings
    - scientific entomological illustration

Thesis Roadmap

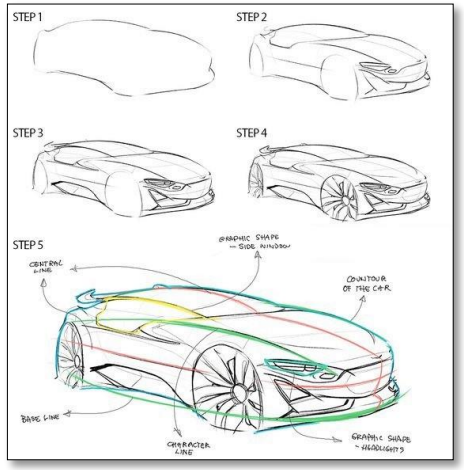
- **Introduction**
  - About this Thesis
  - Importance of Sketches
  - Sketch-based Systems
  - Objectives
- Related Work
- Overview
- Automatic Framework
- Interactive Framework
  - Entomology Application
- Conclusions and Future Directions





Introduction: Importance of Sketches

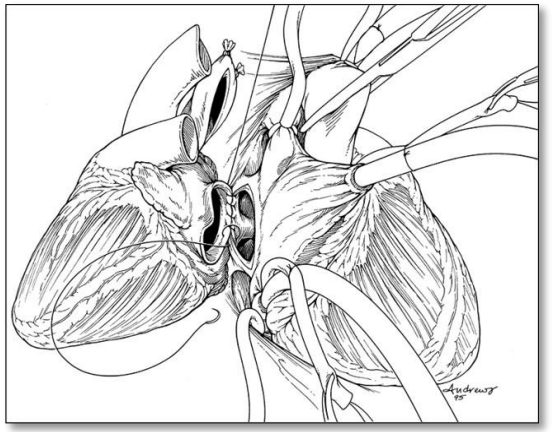
- Sketches, drawings, or designs have been used since the earliest days of humanity
- Several applications
- Domain-valid interpretations



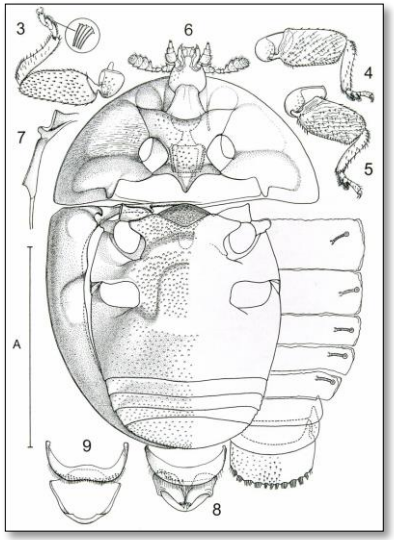
Industrial Design

Architecture

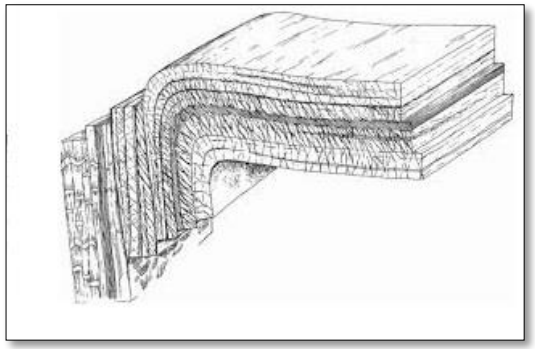
Botany



Medicine



Biology



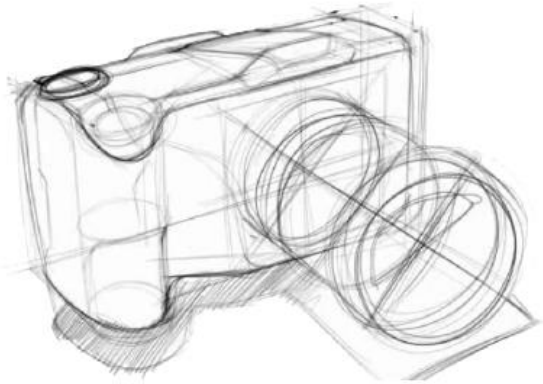
Geoscience

Introduction: Sketch-based Interfaces & Modeling

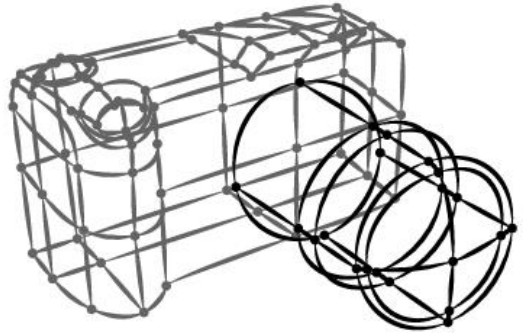
Development communities began to build systems for:

- Modeling
- Animation
- Representation of Objects

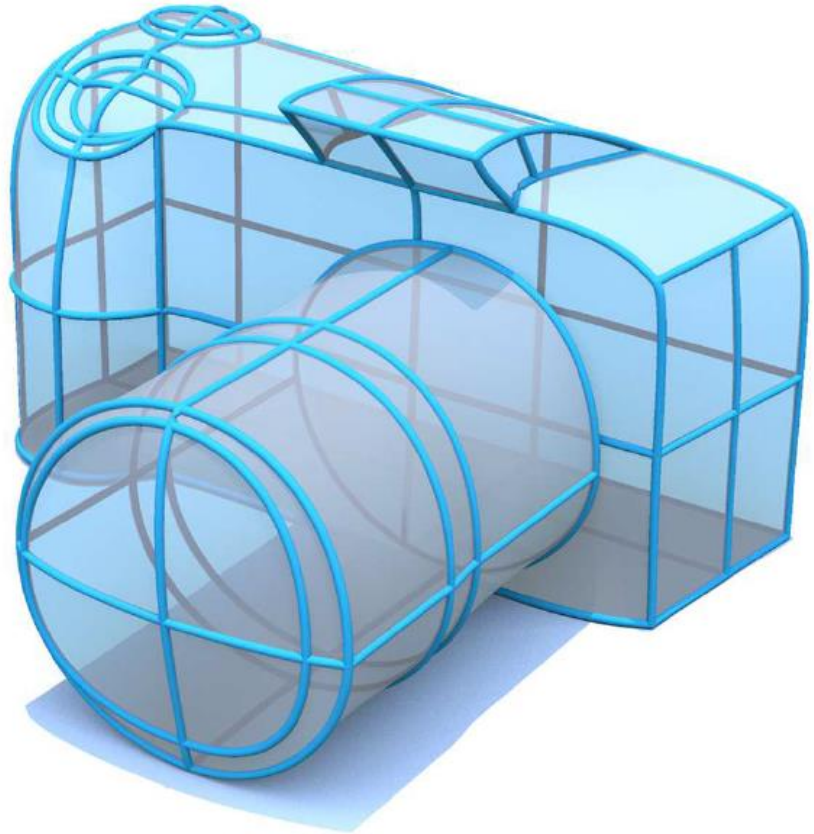
- Creating the concept of Sketch-based Interfaces & Modeling (SBIM)



Inspiration



Input curves



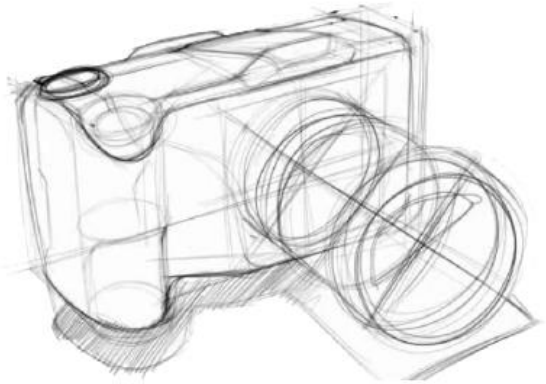
3D Reconstruction

Xu et al. (2014)

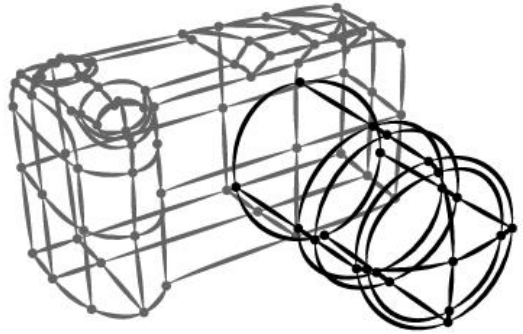
Introduction: Sketch-based Interfaces & Modeling

The field of SBIM introduced a new paradigm

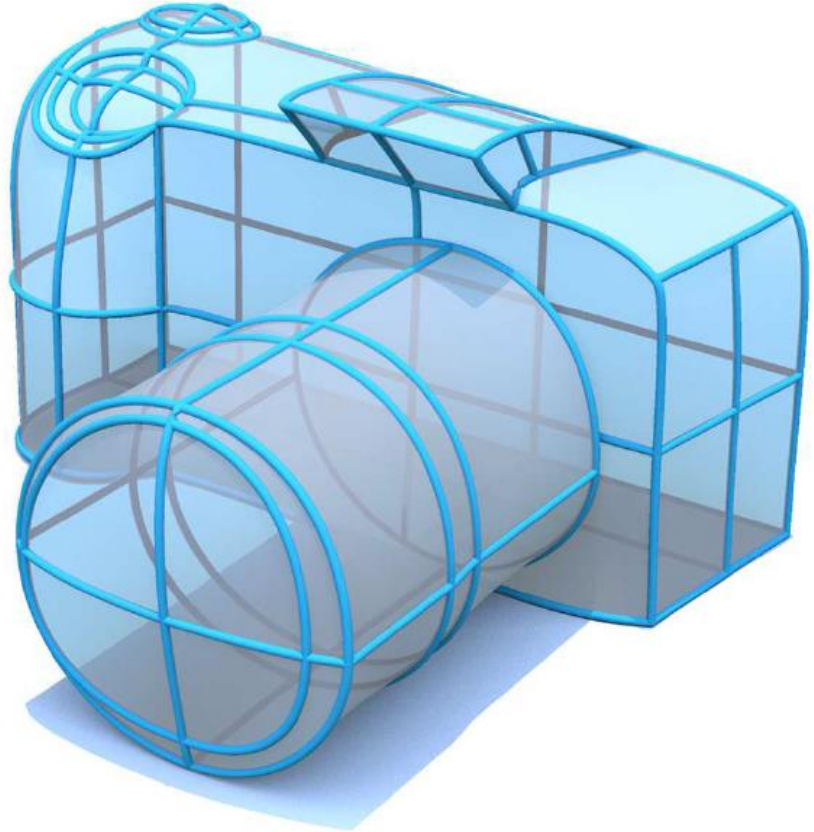
- Traditional Illustrator's drawing
- Rendering Skills
- Build 3D models intuitively and rapidly



Inspiration



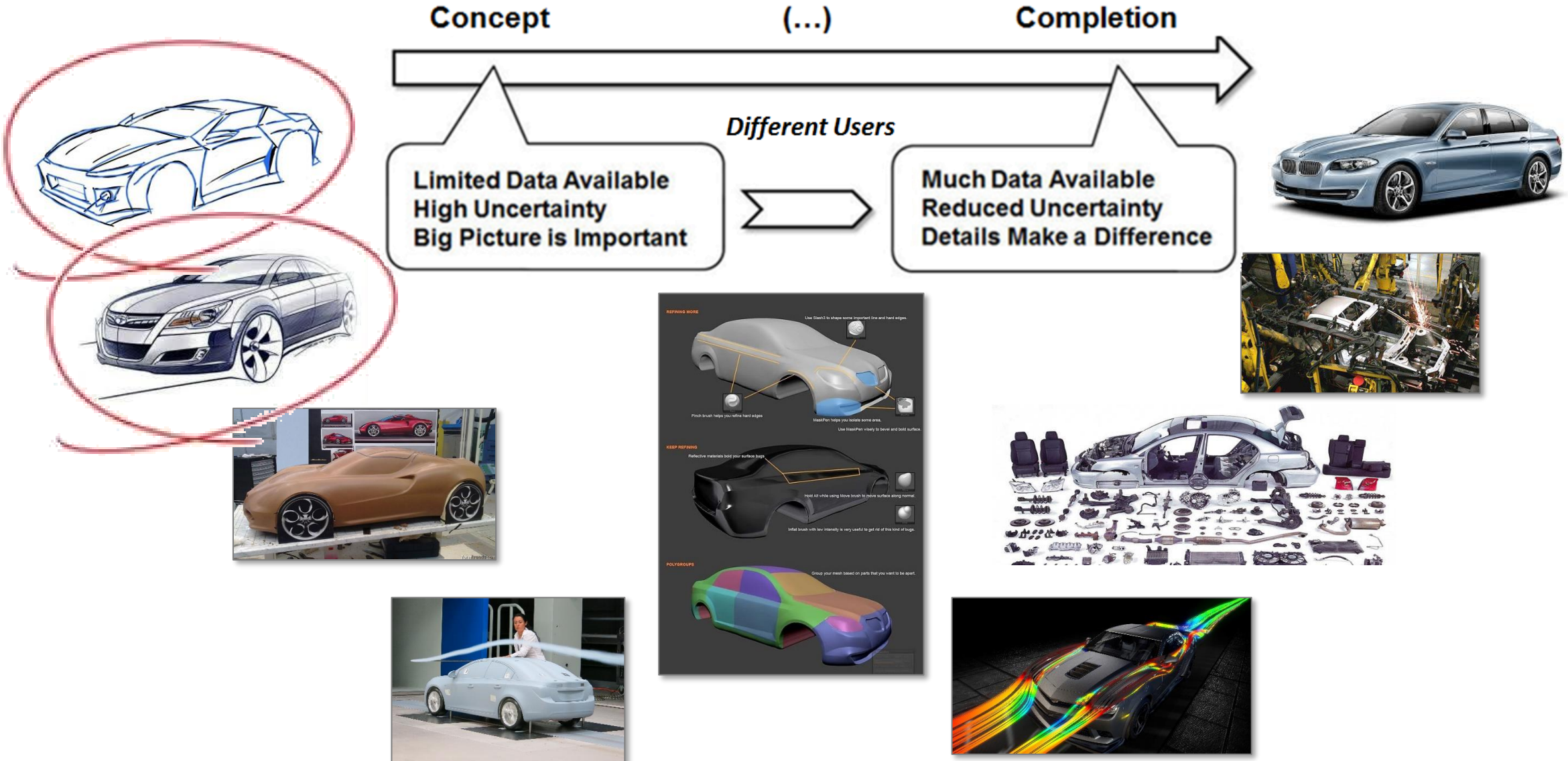
Input curves



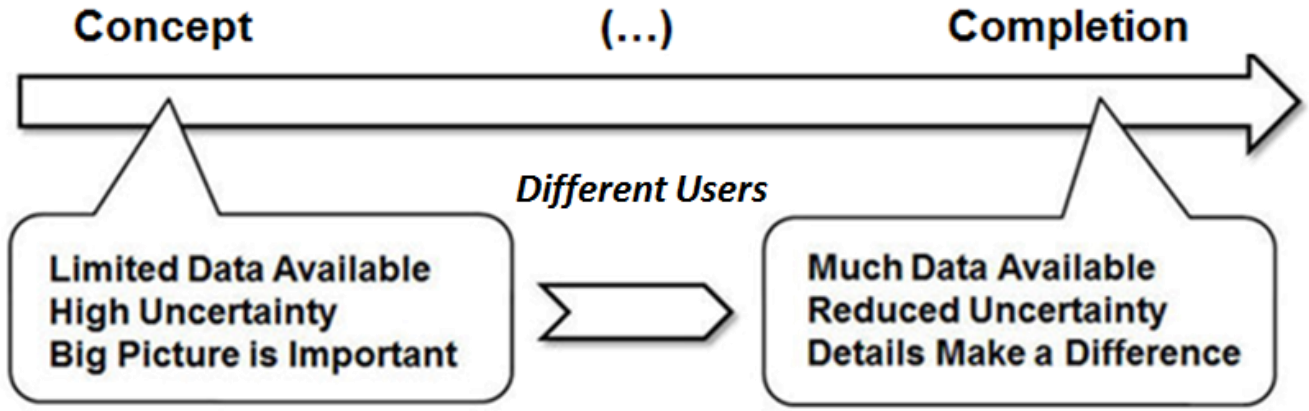
3D Reconstruction

Xu et al. (2014)

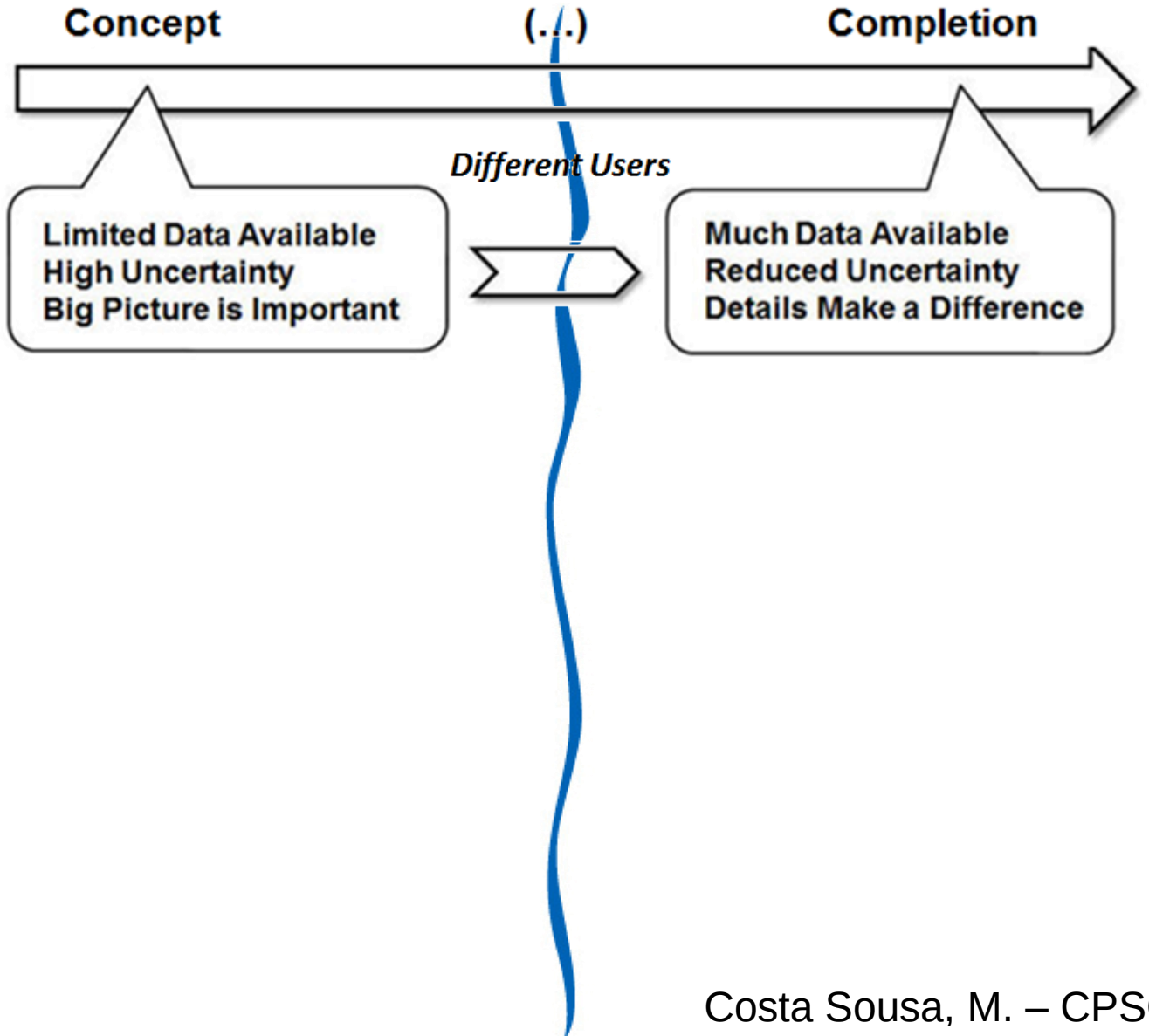
Introduction: Design Workflow



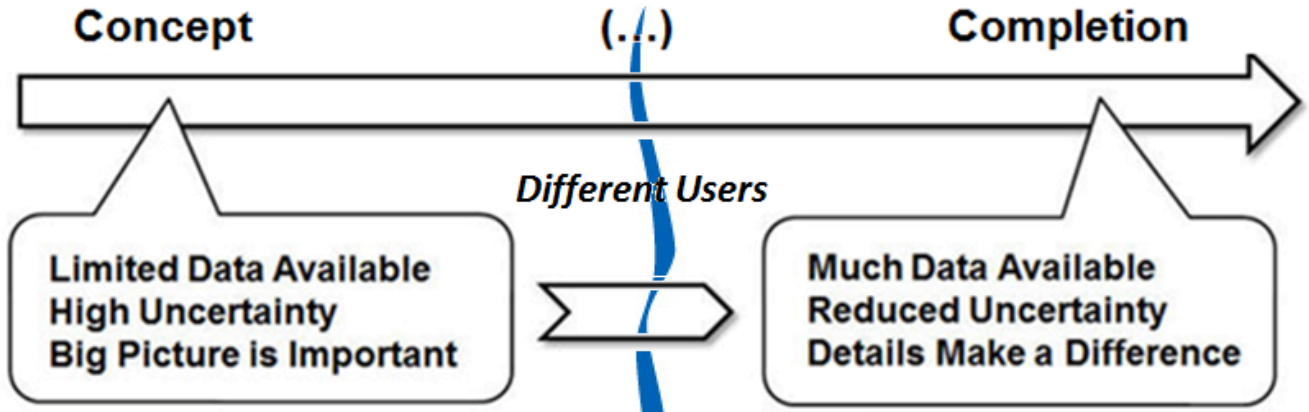
Introduction: Modeling Tools



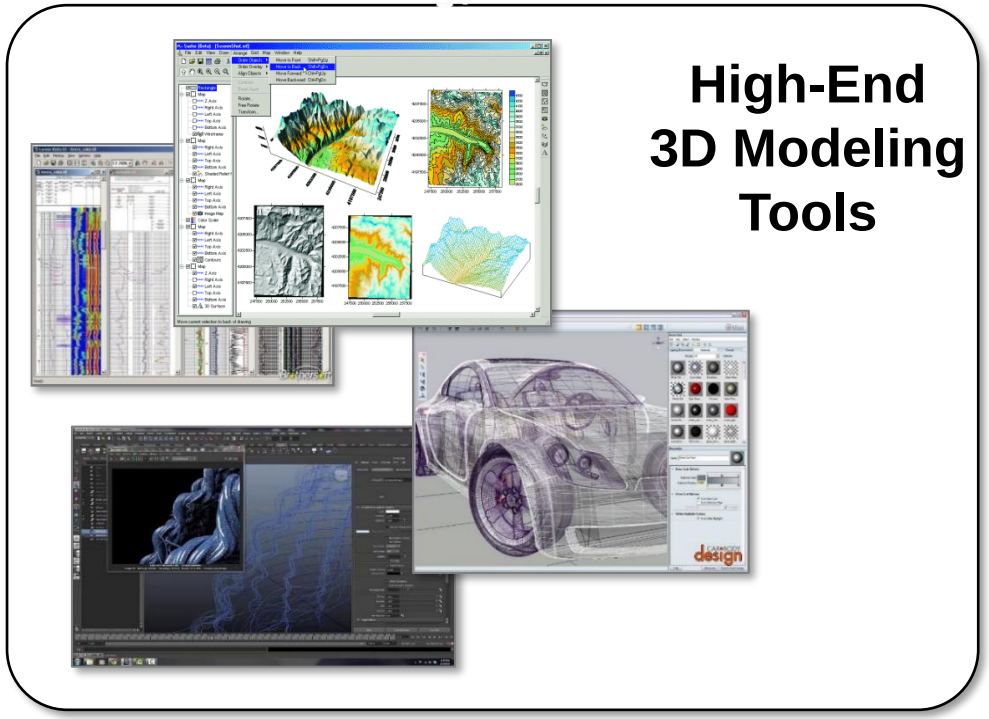
Introduction: Modeling Tools



Introduction: Modeling Tools



Accuracy
+ Details
+ Gradual



Introduction: Modeling Tools

Concept (...) Completion

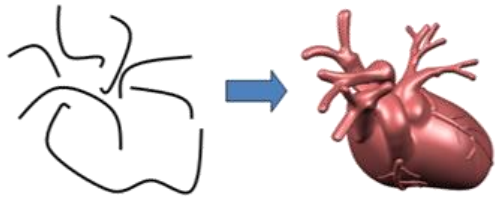
Approximation
+ Storyboarding
+ Fast

Limited Data Available
High Uncertainty
Big Picture is Important

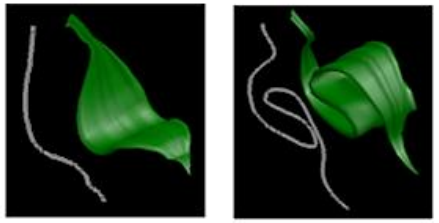
Different Users

Much Data Available
Reduced Uncertainty
Details Make a Difference

Accuracy
+ Details
+ Gradual



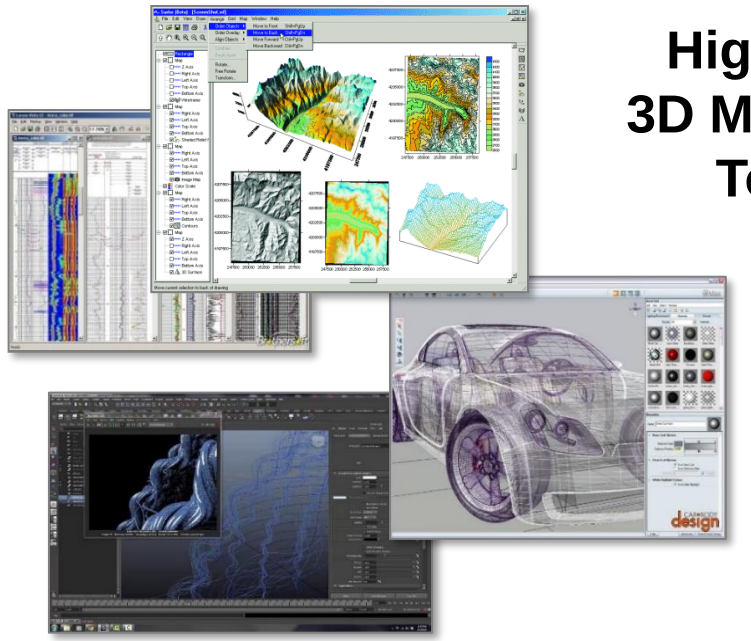
Overall Form



Operators

Shape Augmentation

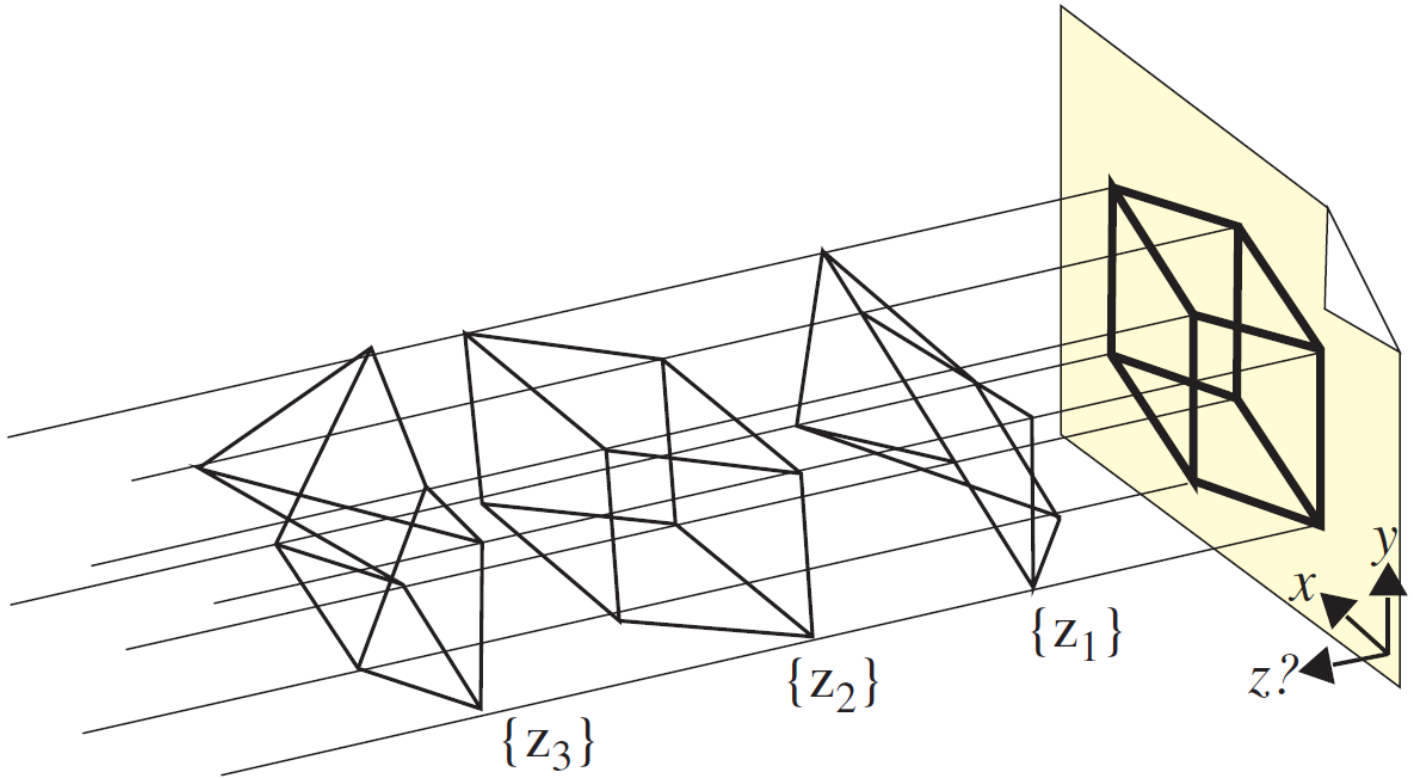
SBIM



High-End
3D Modeling
Tools

Introduction: Main Issues

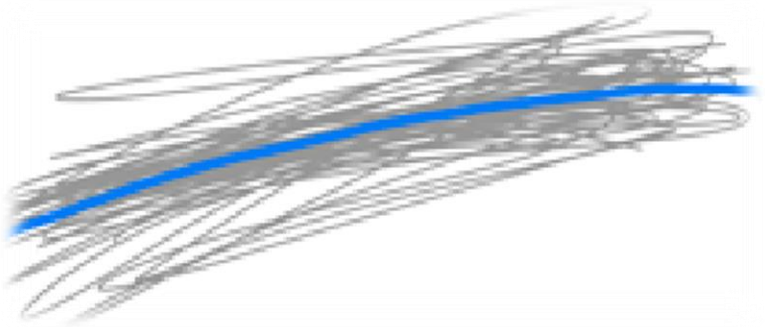
A drawing can contain numerous interpretations.



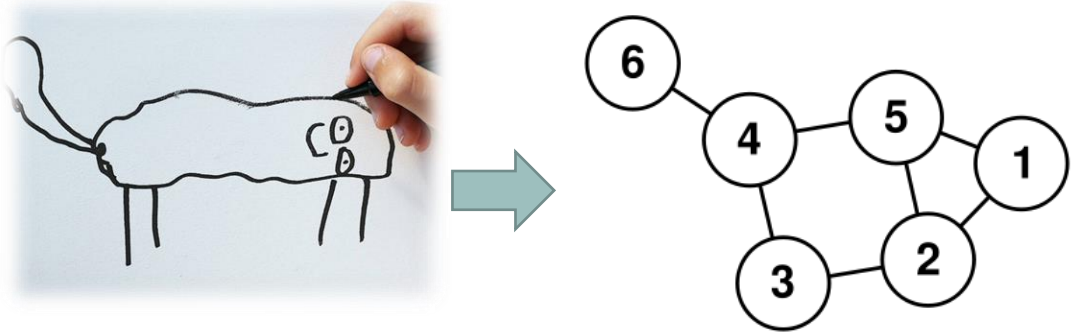
Olsen et al. (2009)

Introduction: Main Issues

Input Acquisition



Smoothing and Resampling

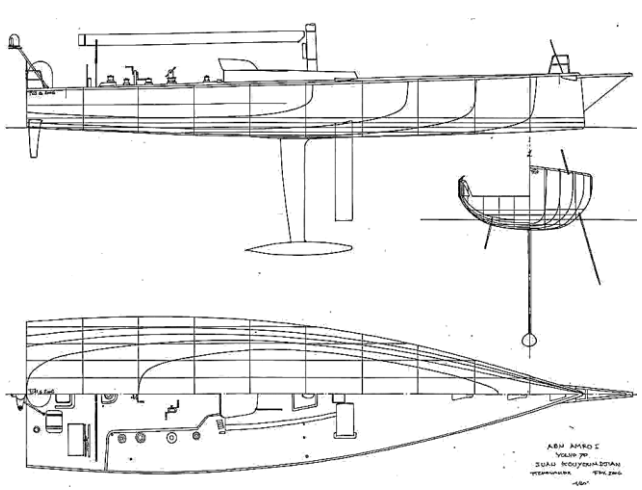


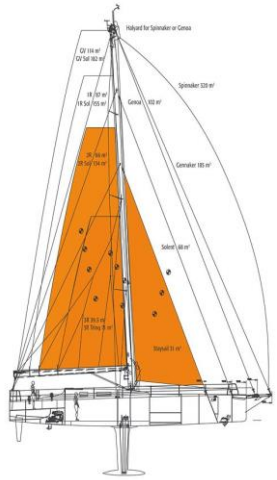
Computational Representation

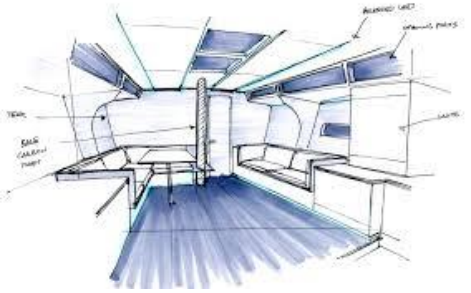
Besides, a series of limitations:

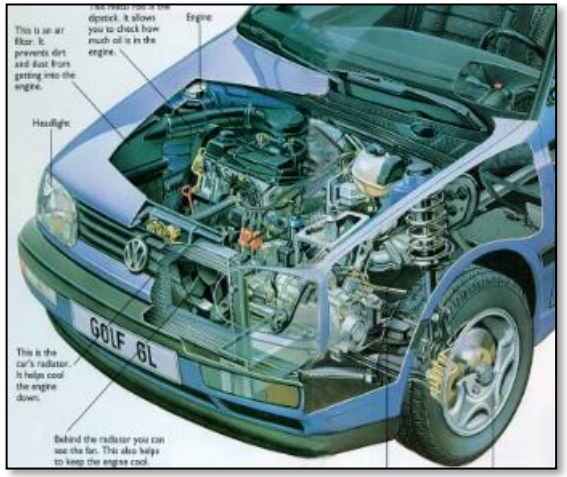
- Acquisition of Drawings
- Computational Representation
- Noises
- Smoothing of Contours
- Re-sampling
- Interpretation by an algorithm

Introduction: Visual Communication Goal









Information transported by the image?

Introduction: Visual Communication Goal

Which one is better:

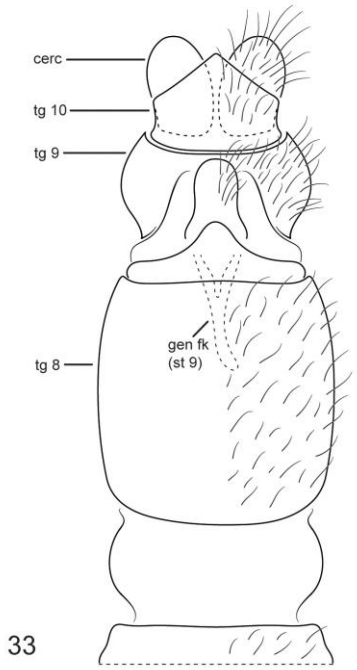
- Photos or Sketches?

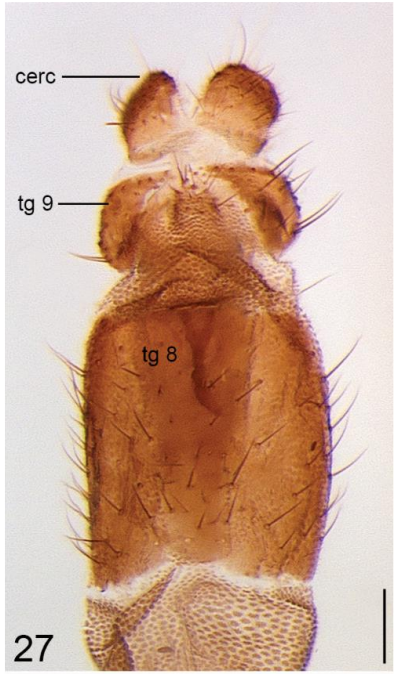
Sketches

- NPR*

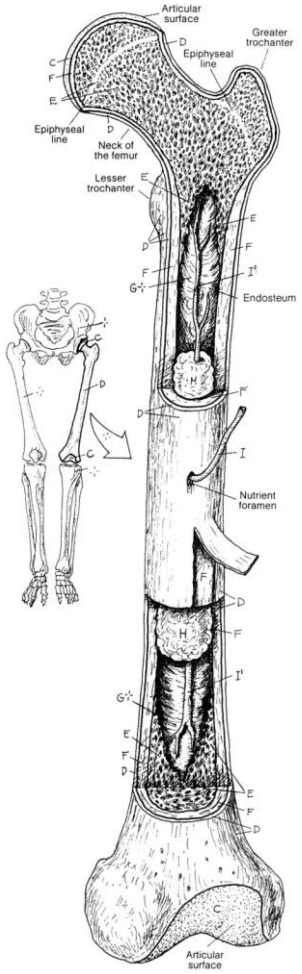
Entomology

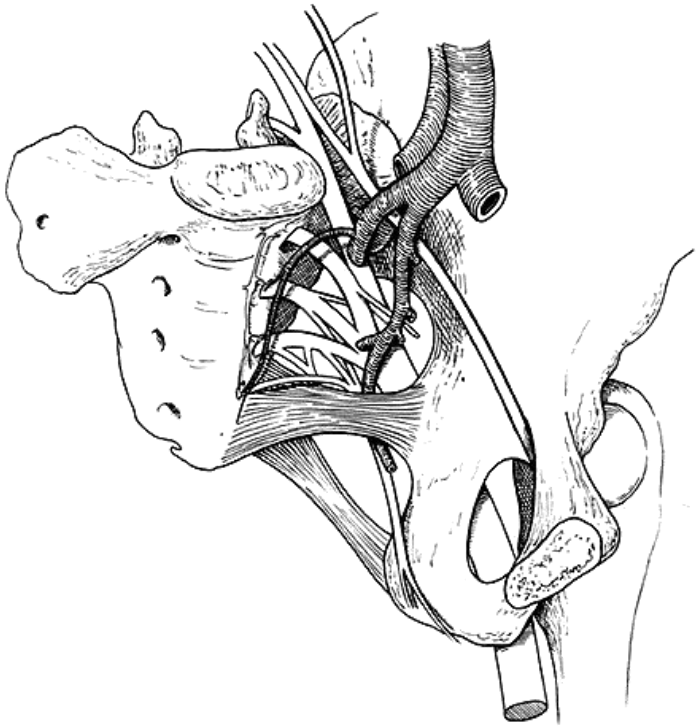
- Lack of data
- *in situ*





Fachin et al. (2018)

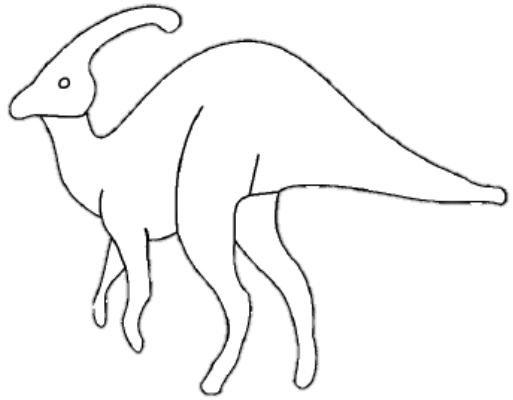


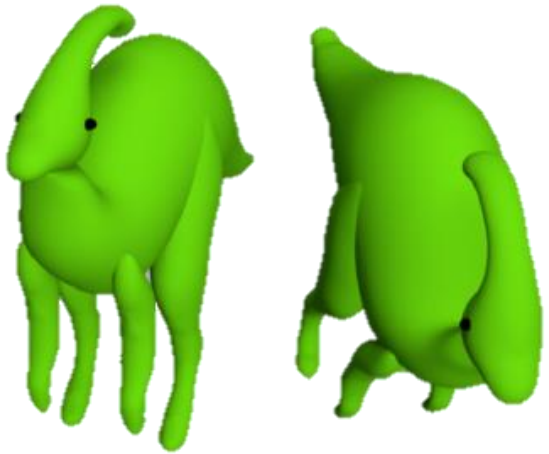


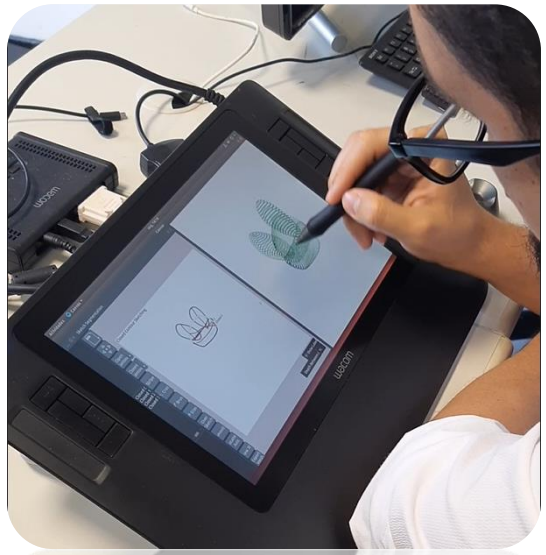
*Non-Photorealistic rendering

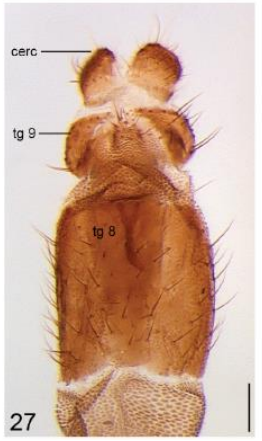
Introduction: Objectives

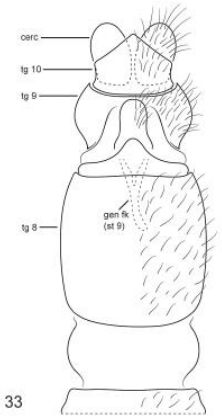
- **Investigate automatic 3D reconstruction**
  - Proposing segmentation strategies
  - Increasing details that can be reconstructed
- **Propose a Sketch-Based System**
  - 2D representation of overlays
  - 3D reconstruction for different contours
- **Model entomological features**
  - Species descriptions of the order Diptera, known as flies and mosquitoes.





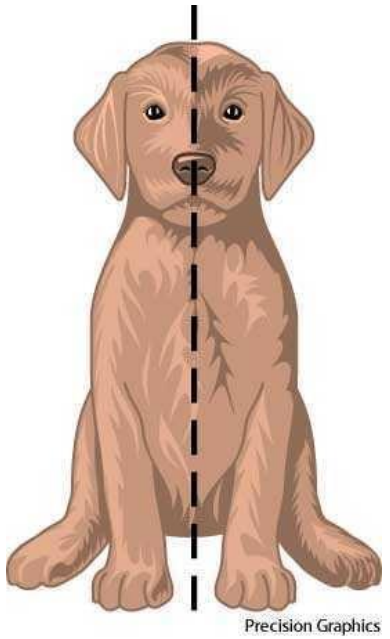


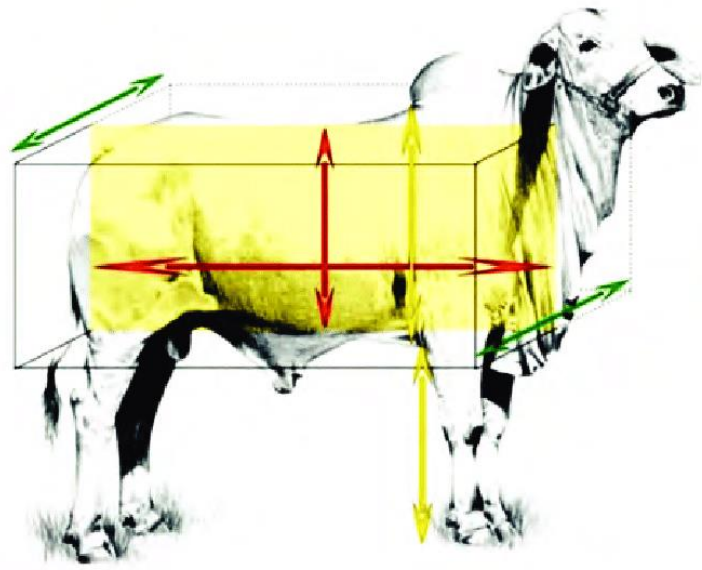


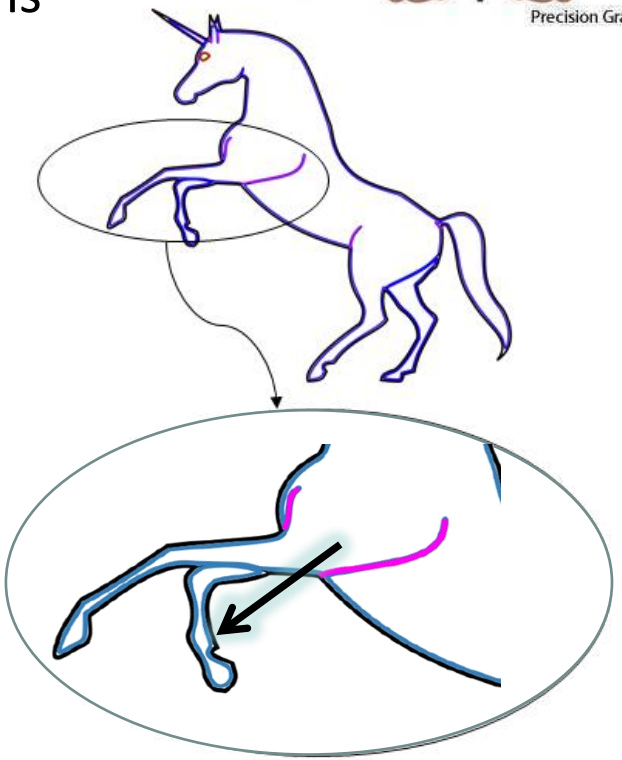


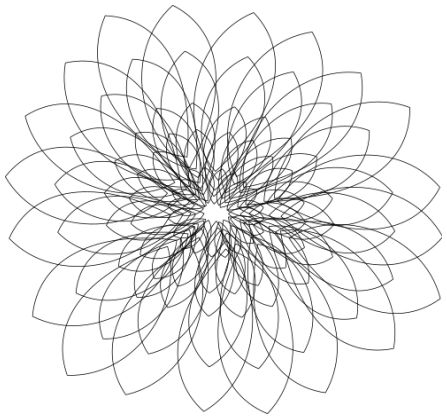
Introduction: Hypotheses

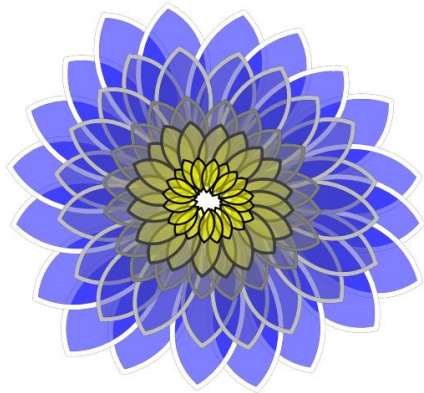
- Work on a specific family of objects or surfaces
- Make use of the estimated proportions present in the sketches
- Curves and Indicative Lines
- Visual Perception Enhancements











Introduction: Publications and Submissions

Ramos, S., Gois, J. P. (2017). **Reconstrução 3D de Sketches em Vista Lateral.** I Workshop @NUVEM - UFABC, Santo Andre - Brasil.

Ramos, S., Trevisan, D. F., Batagelo, H. C., Costa Sousa, M. & Gois, J. P. (2018). **Contour-aware 3D reconstruction of side-view sketches**. Computers & Graphics, 77, 97-107.

Ramos, S., Santos, C. M. D., Costa Sousa, M. & Gois, J. P. (2020). **Sketch-based modeling supported by 2D visual perception enhancements: application and analysis for illustrations of systematic biology**. (Submitted to Computer & Graphics).

Ramos, S., Santos, C. M. D., Costa Sousa, M. & Gois, J. P. (2021). **An interactive framework for sketch-based modeling of systematic biology.** (Planned for GNSI Conference)*.

*Guild of Natural Science Illustrators Forum

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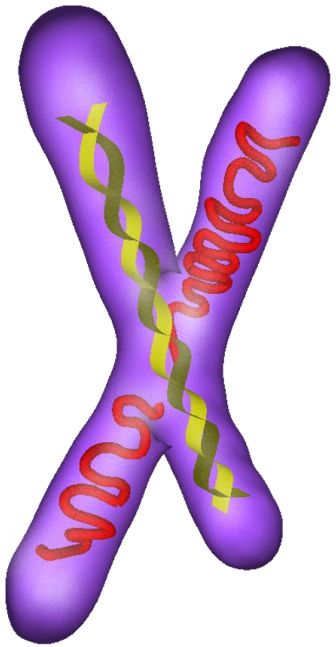
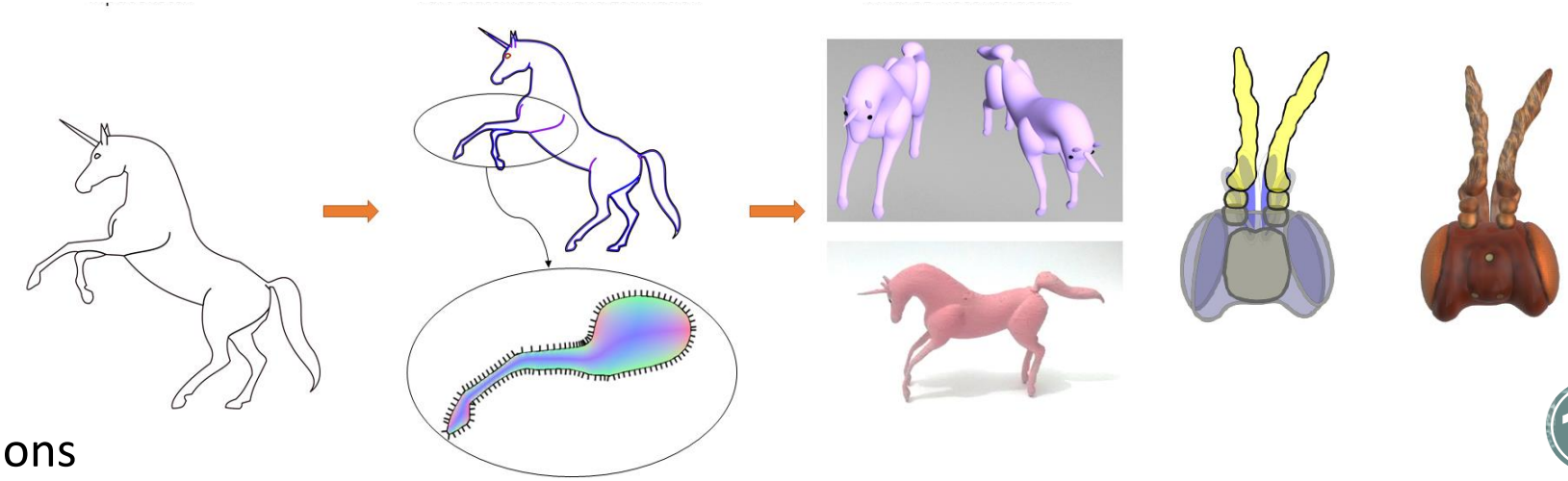
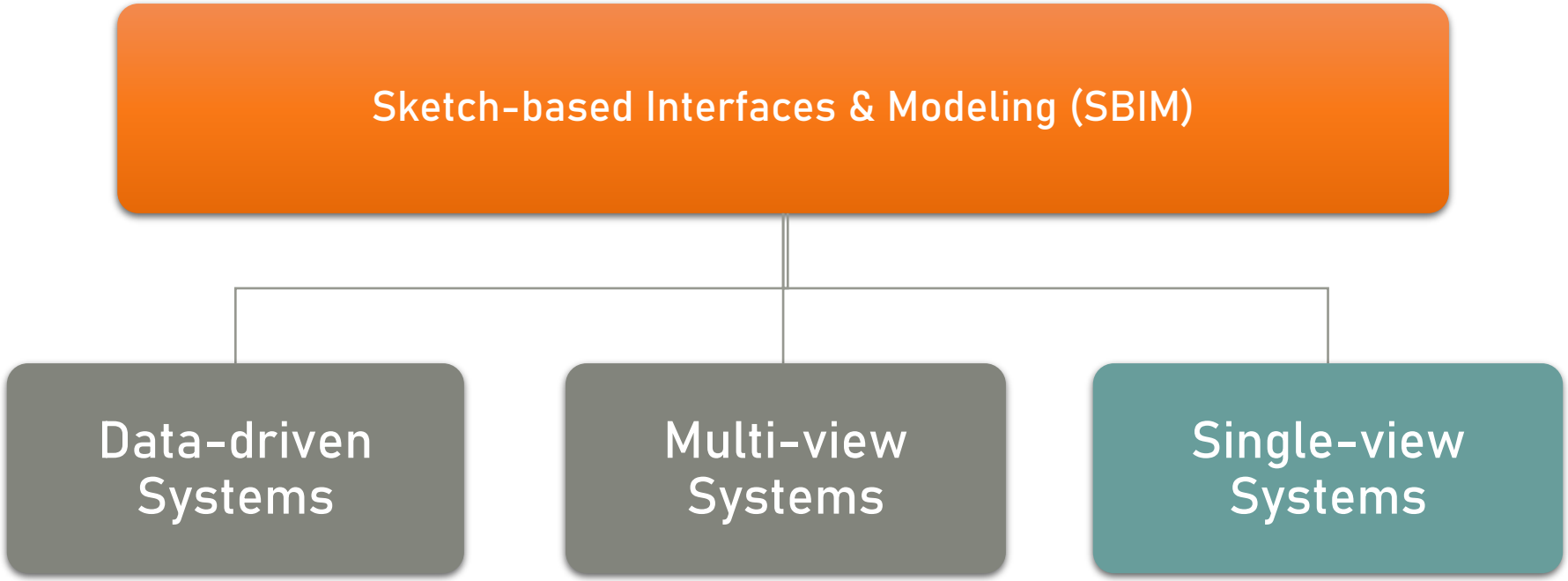
  - Objectives
- **Related Work**
- Overview
- Automatic Framework
- Interactive Framework
  - Entomology Application
- Conclusions and Future Directions



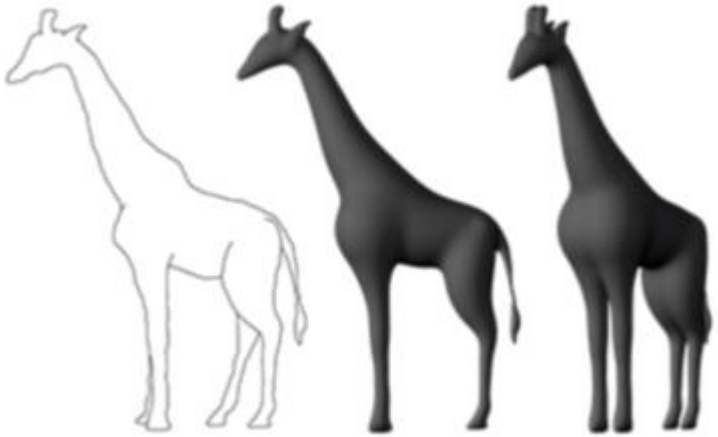


Related Work: Single-view Systems



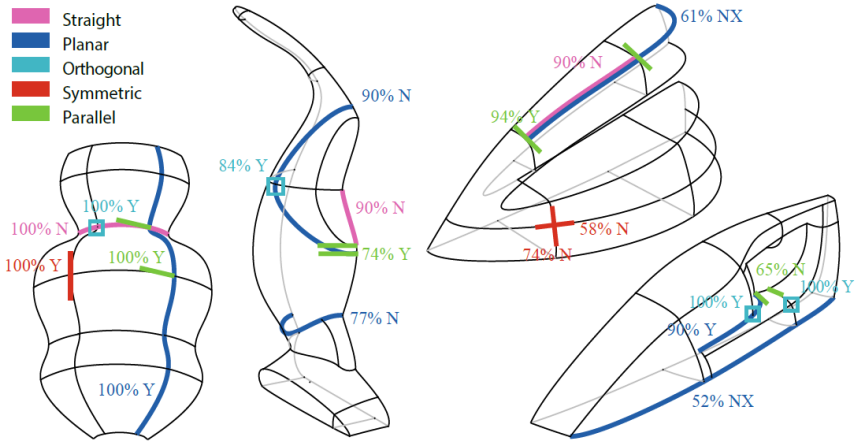
- Interpret and infer the reconstruction
- Imposing some constraints
- Mimics the human ability to see 2D representations of 3D objects

Related Work: Single-view Systems

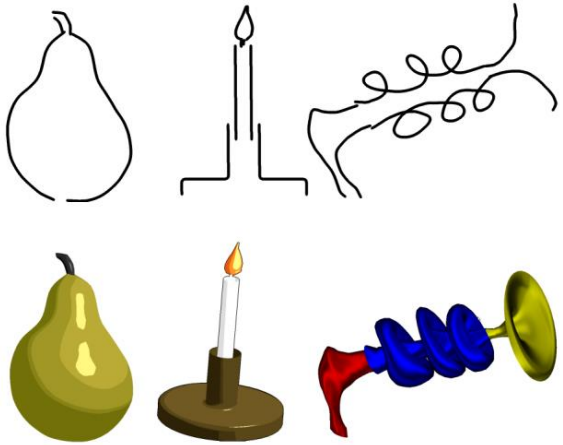


Entem et al. (2014)

Sýkora et al. (2014)



Xu et al. (2014)



Cherlin et al. (2005)

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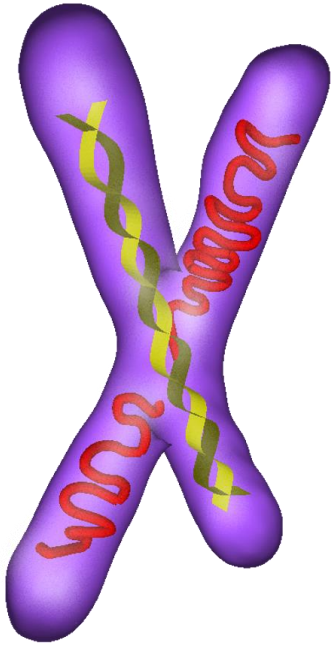
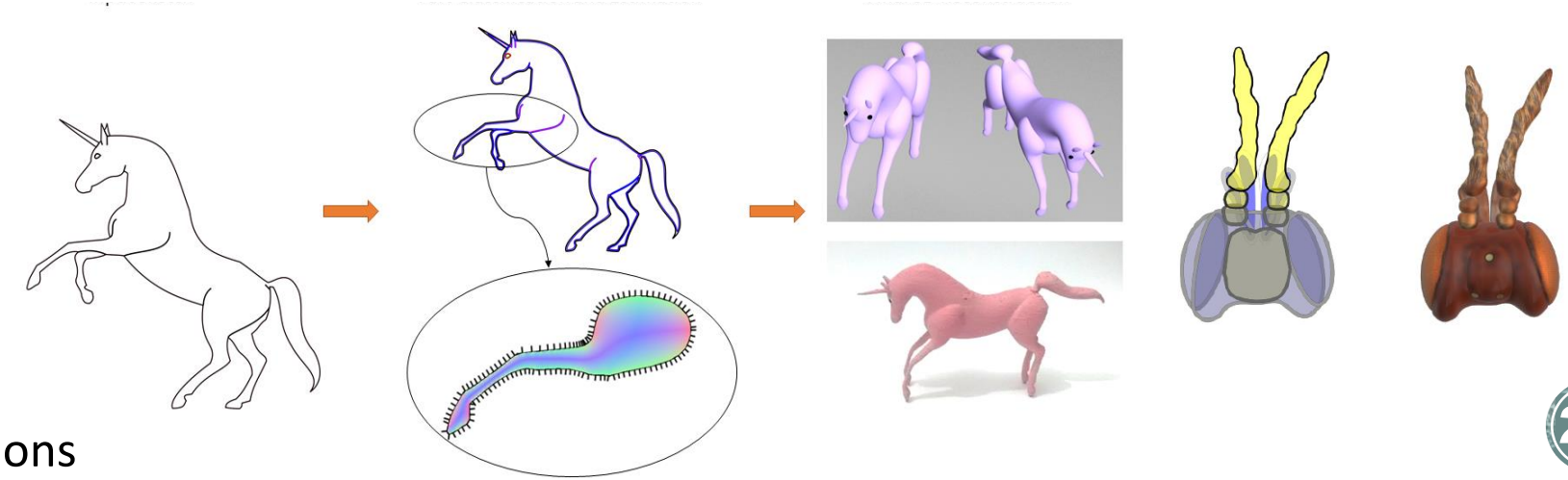
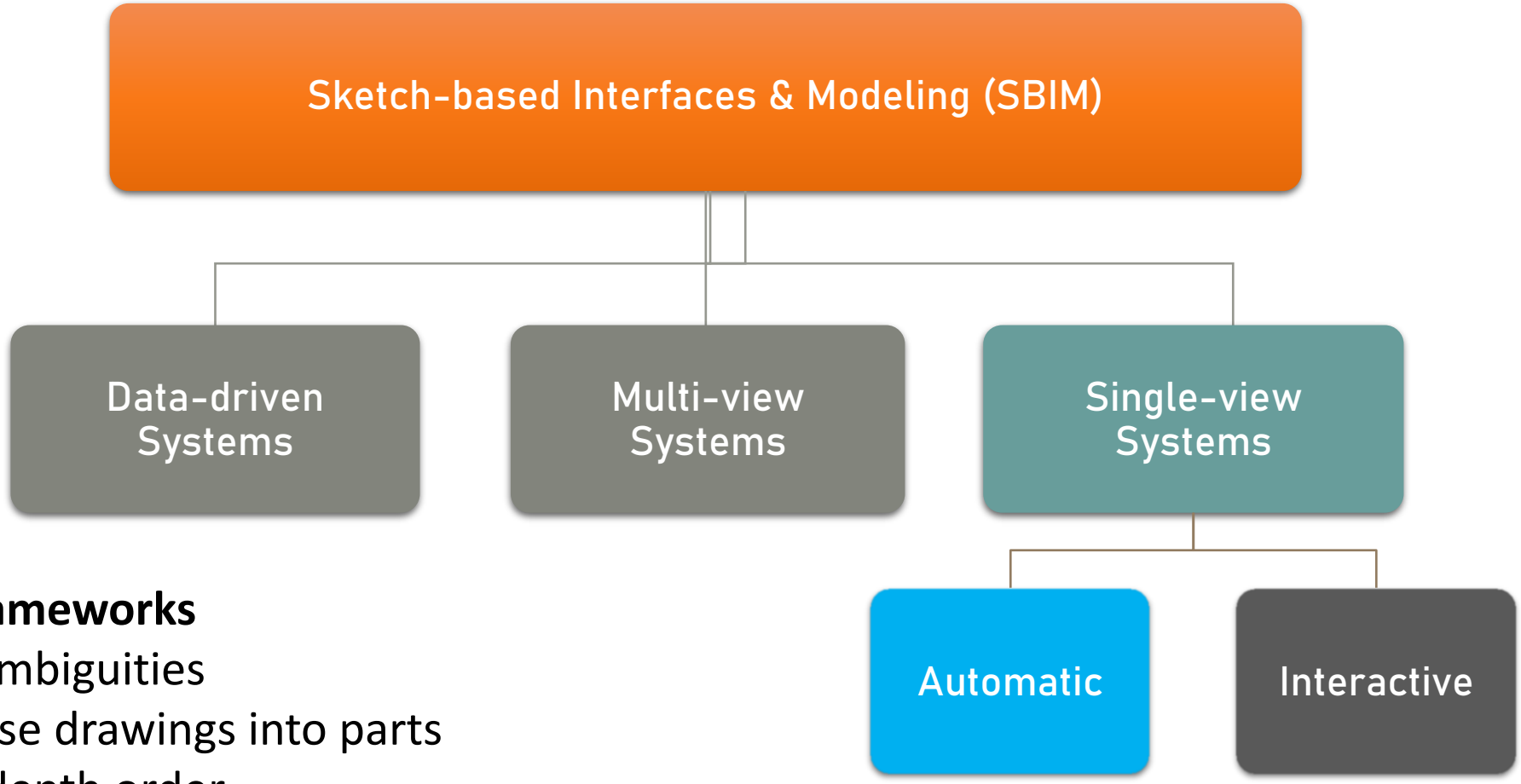
- Conclusions and Future Directions





Overview: Automatic Framework



Automatic frameworks

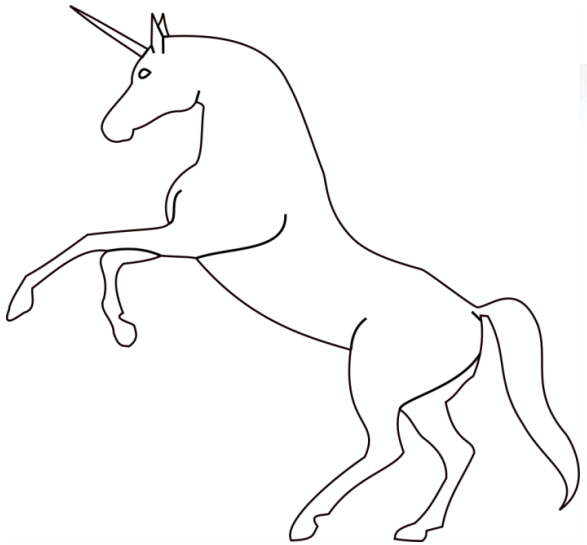
- Analyze ambiguities
- Decompose drawings into parts
- Define a depth order
- 3D shape for reconstruction

Overview: Automatic Framework Contributions

Contour-Aware 3D Reconstruction of Side-View Sketches (Chapter 4).

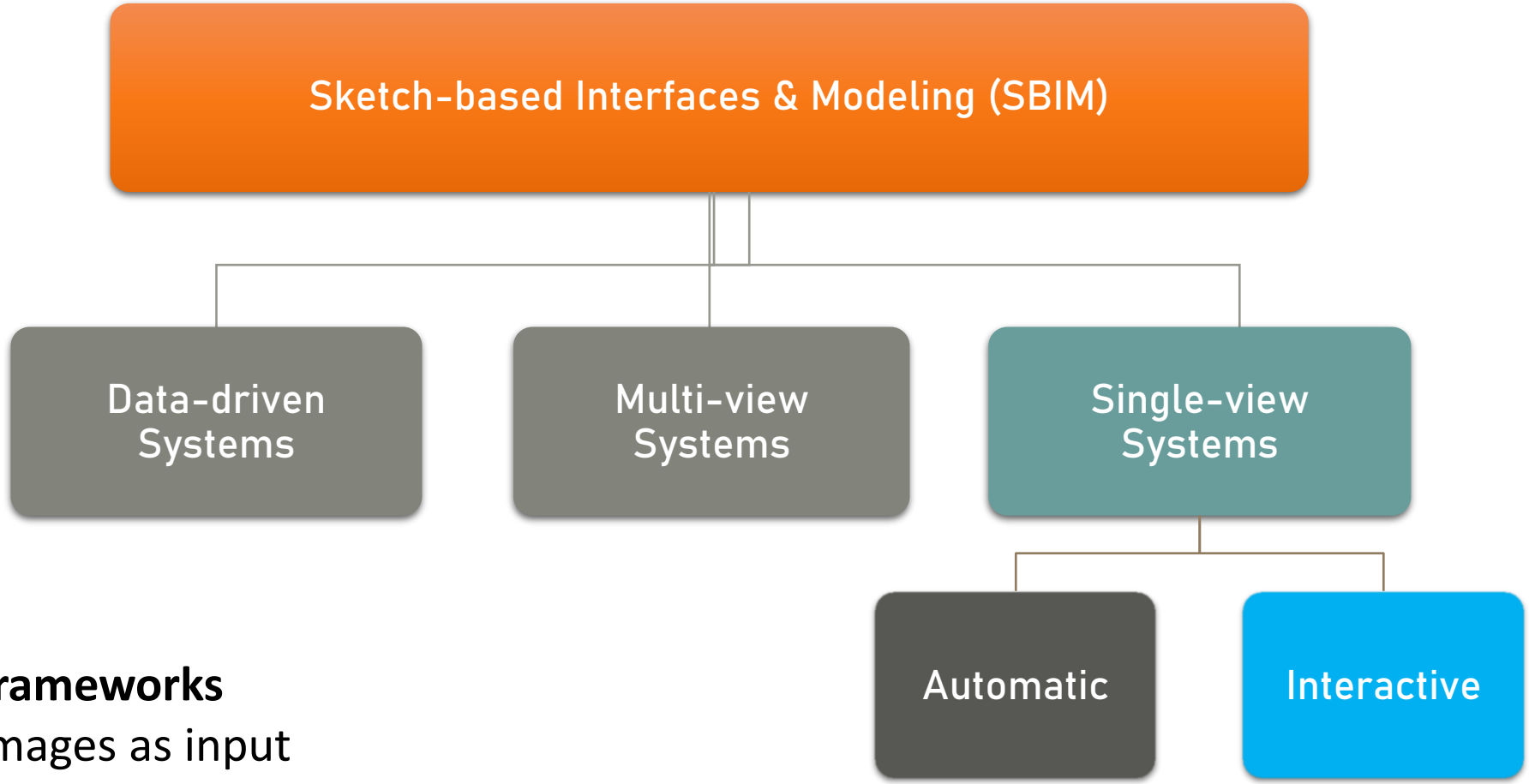
- new classification for reconstruction of parts discarded in previous work
- skeleton-free 3D reconstruction
- guarantee of interpolation of contours
- the flexibility to flatten or round shapes

Input Sketch



Printed 3D Model

Overview: Interactive Framework



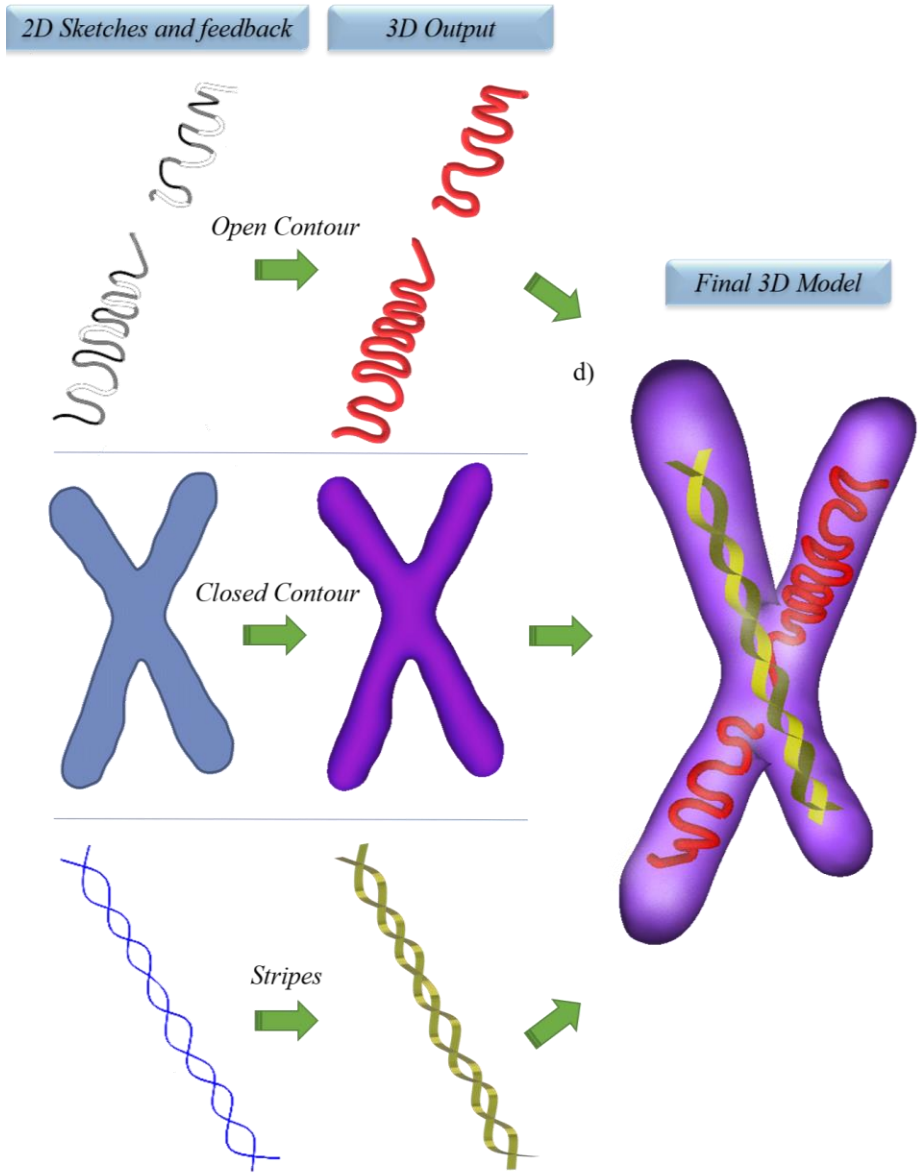
Interactive frameworks

- Can use images as input
- User interactively draw
- Hint clues over the image or drawing

Overview: Interactive Framework Contributions

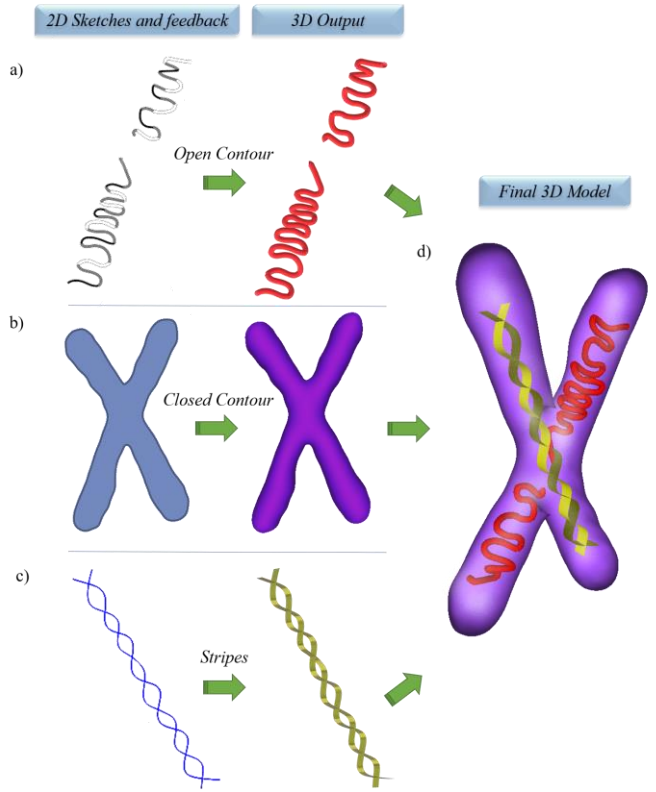
Sketch-based modeling supported by 2D visual perception enhancements (Chapter 5).

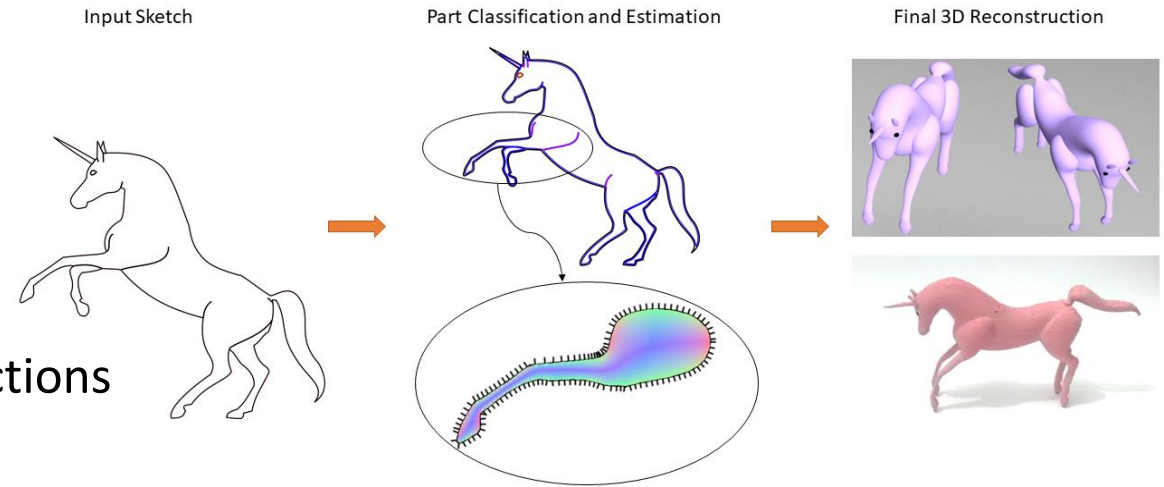
- a novel framework for overlaying contours
- a set of visual effects to create layered objects
- the assembly of 3D reconstruction methods
- a novel method modeling strings and stripes
- an application and analysis for biological systematic illustrations

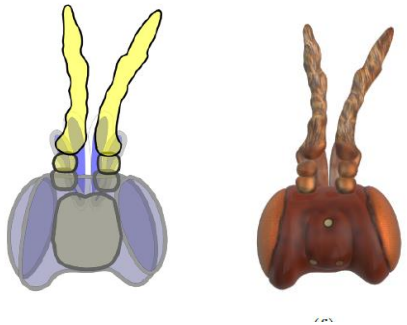


Thesis Roadmap

- Introduction
  - About this Thesis
  - Importance of Sketches
  - Sketch-based Systems
  - Objectives
- Related Work
- Overview
- **Automatic Framework**
- Interactive Framework
  - Entomology Application
- Conclusions and Future Directions

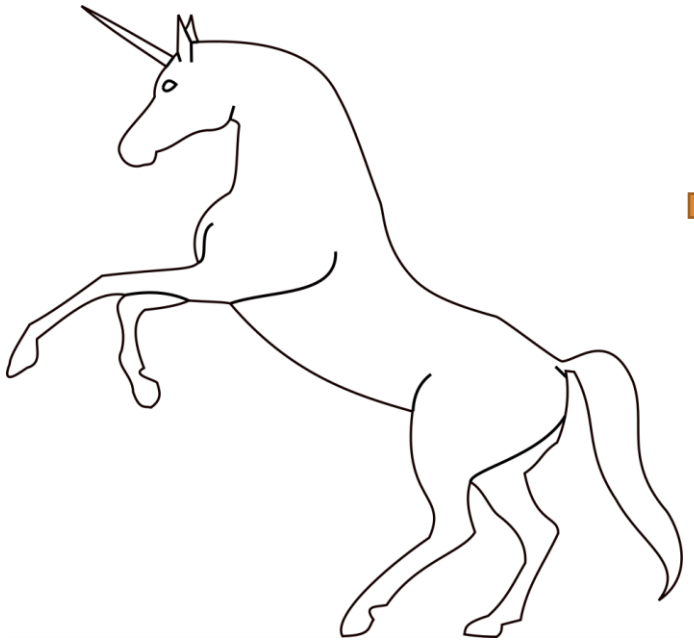




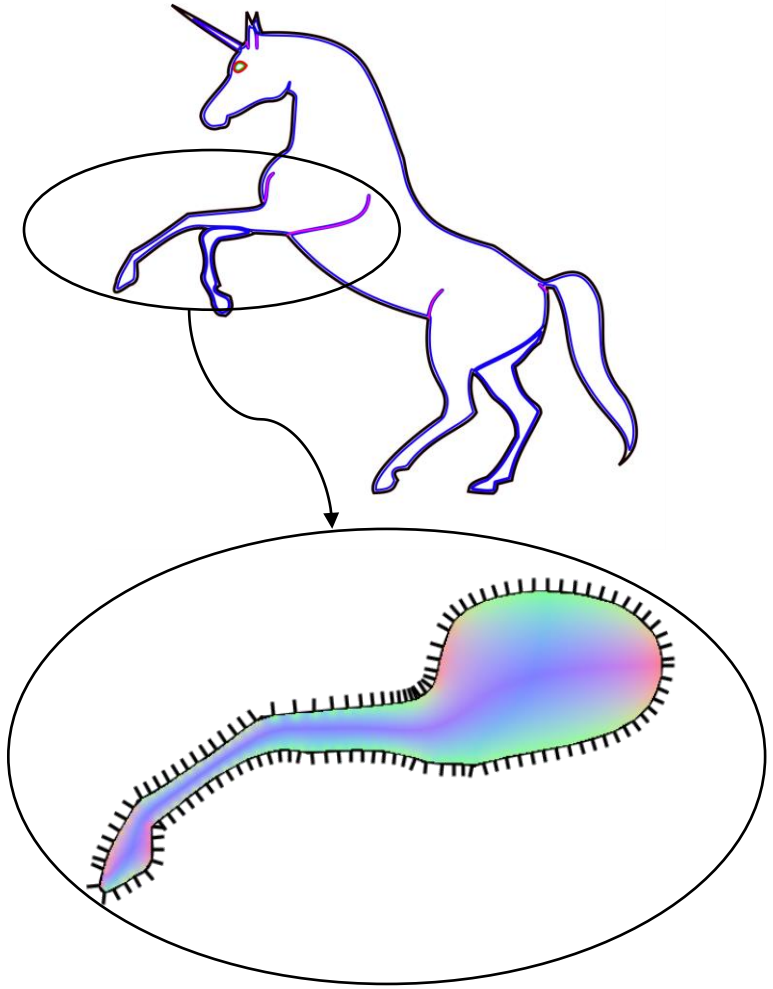


Automatic Framework: Introduction

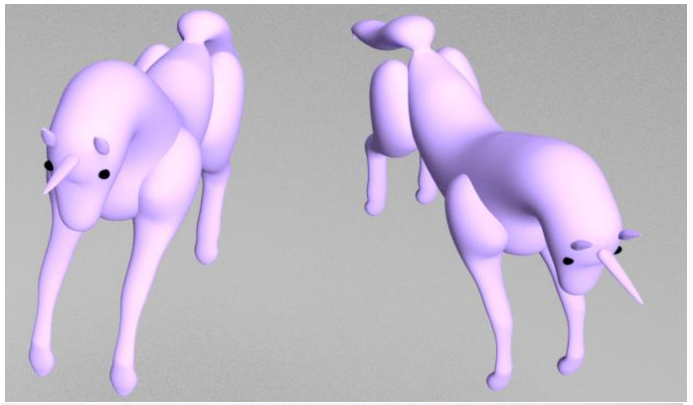
Input Sketch



Part Classification and Estimation



Final 3D Reconstruction

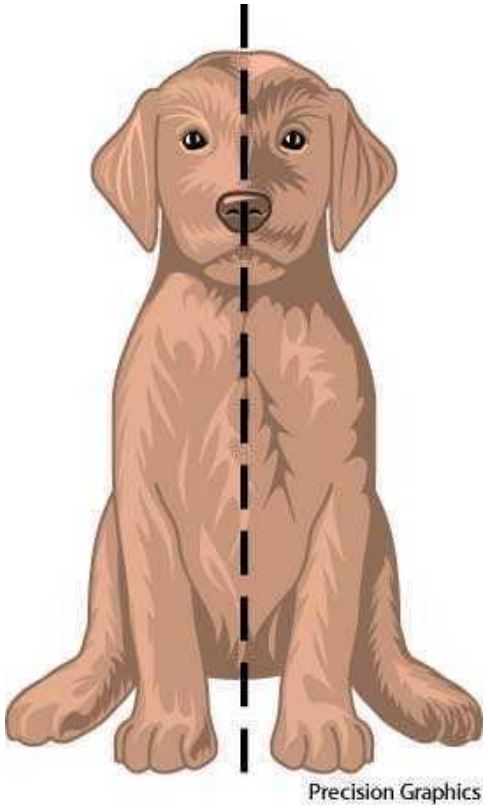


Published on Computer & Graphics

Automatic Framework: Introduction

- Effective approaches reconstruct a specific family of surfaces or objects.
  - Structural symmetry

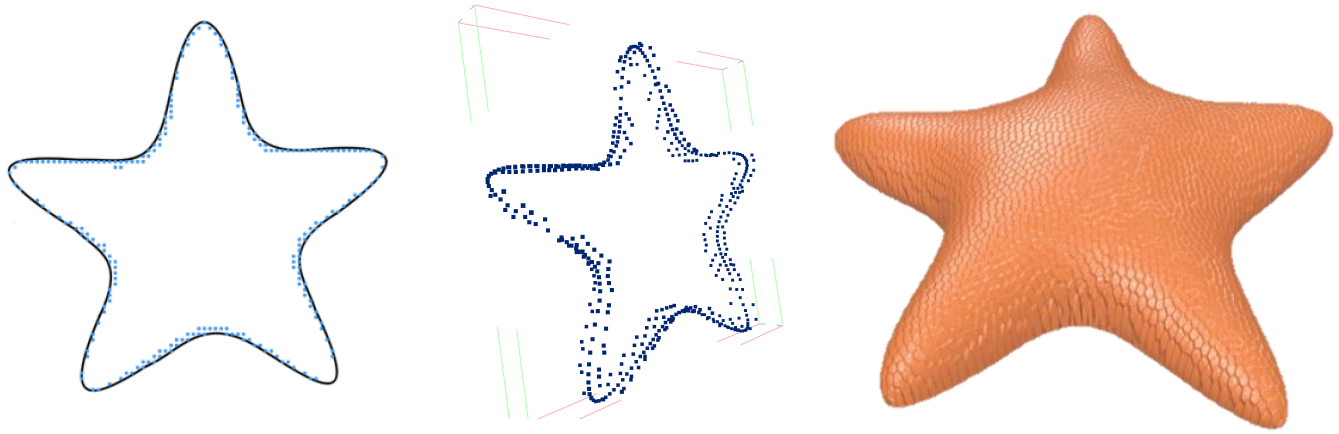
- 3D reconstructions: foreground parts are replicated in the background.



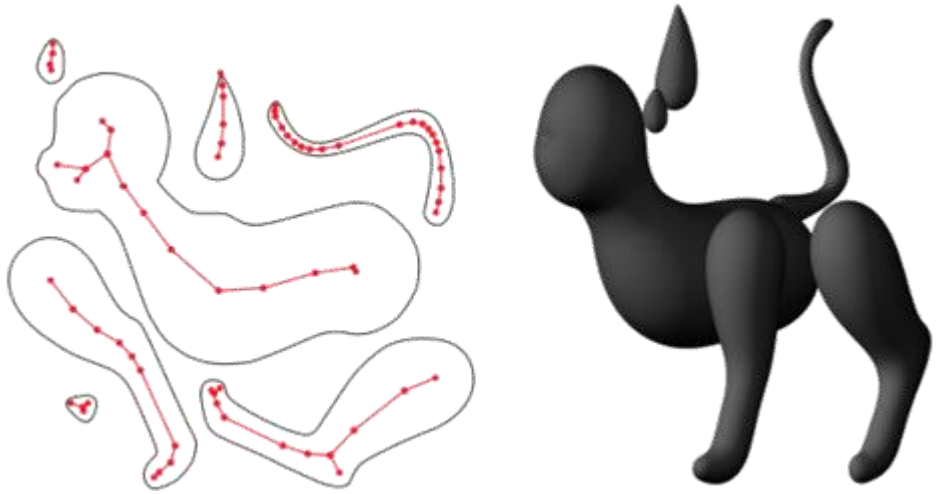
Automatic Framework: Introduction

Preserves the sketch contours by interpolating points on strokes

Estimated relief and depth



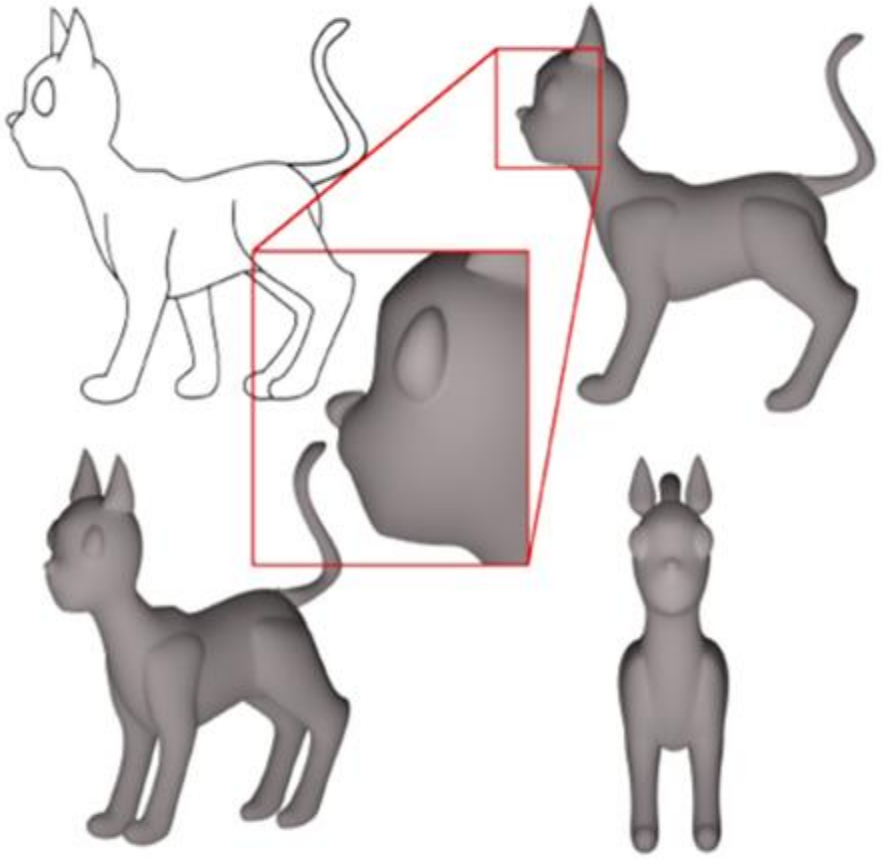
- Estimated relief and depth



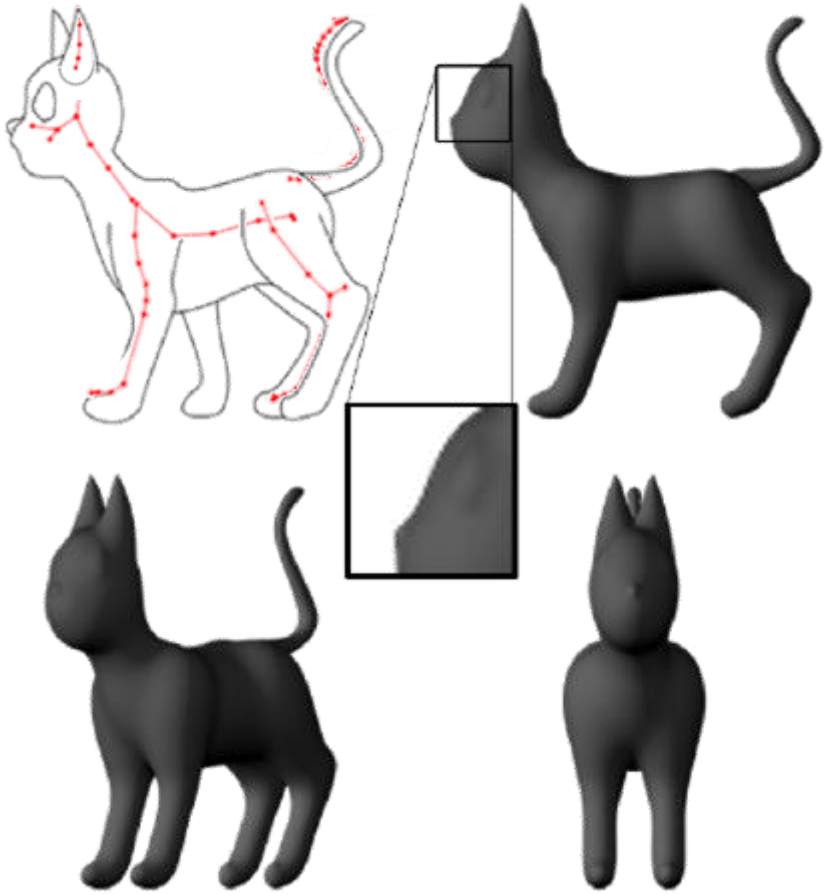
- Generalized surfaces along a skeleton

Entem et al. (2014)

Automatic Framework: Introduction

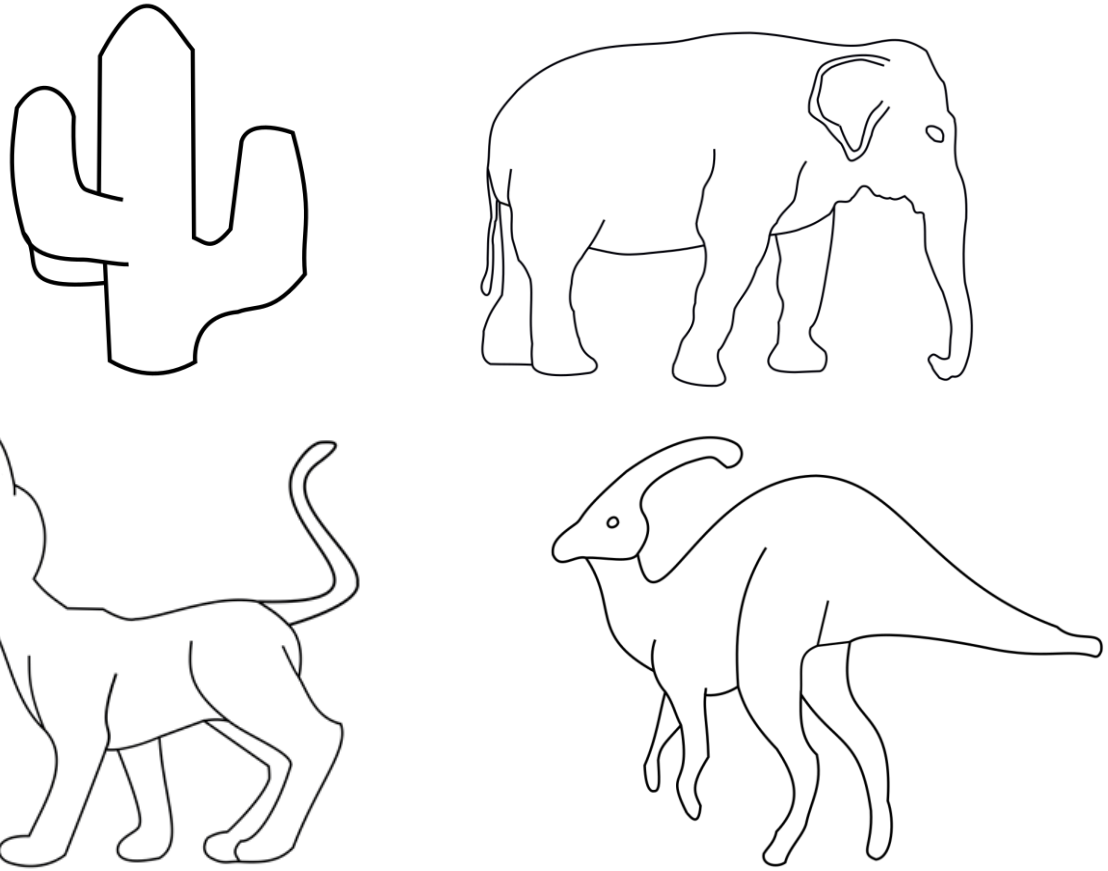


Our method capture details



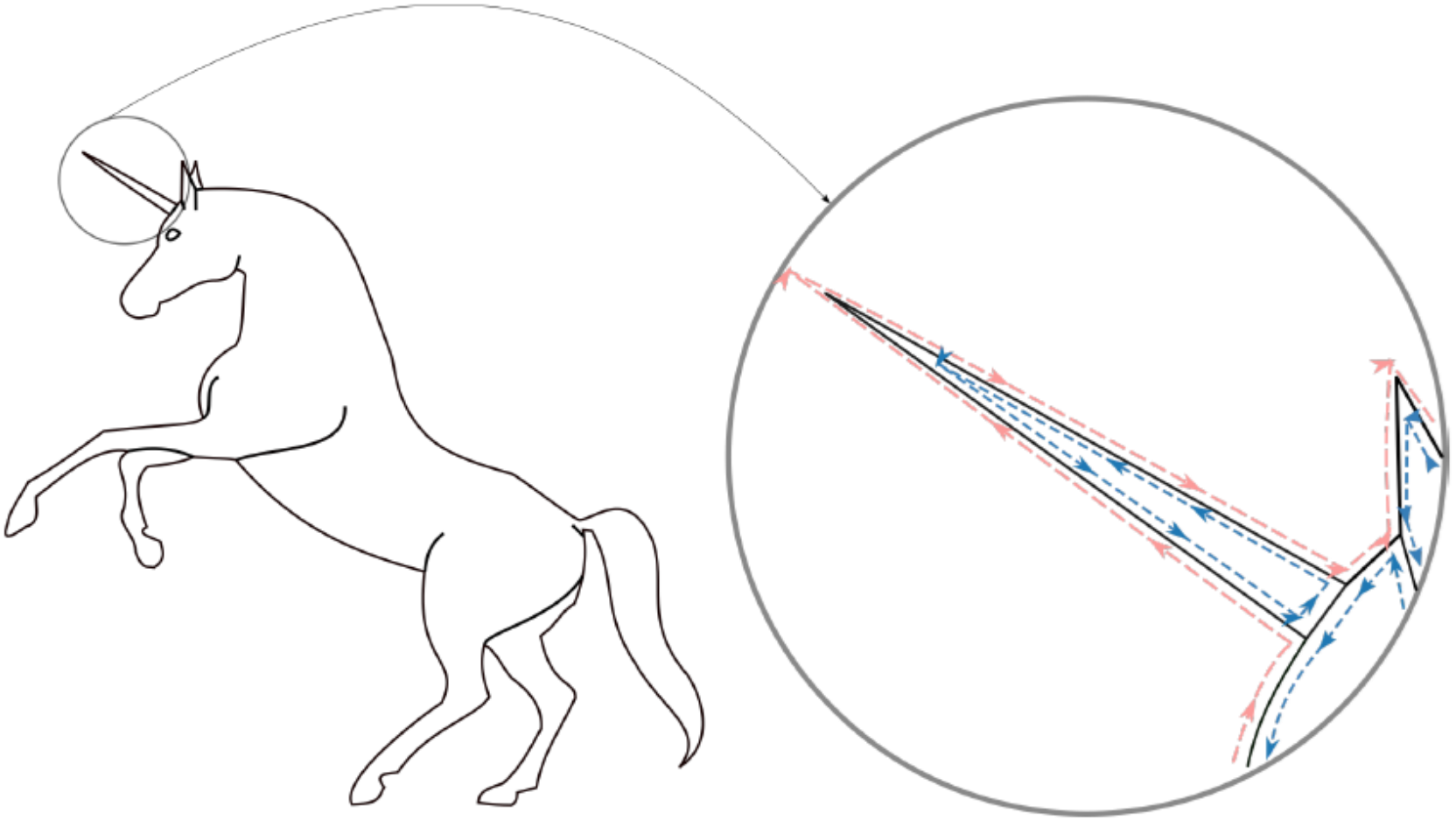
Entem et al. (2014), not interpolate

Automatic Framework: Input



- Digital Sketches
- Adequately filtered
- Cases such as oversketching have already been resolved
- Have at least one closed contour
- Do not present self-intersections or cross-sections

Automatic Framework: Input

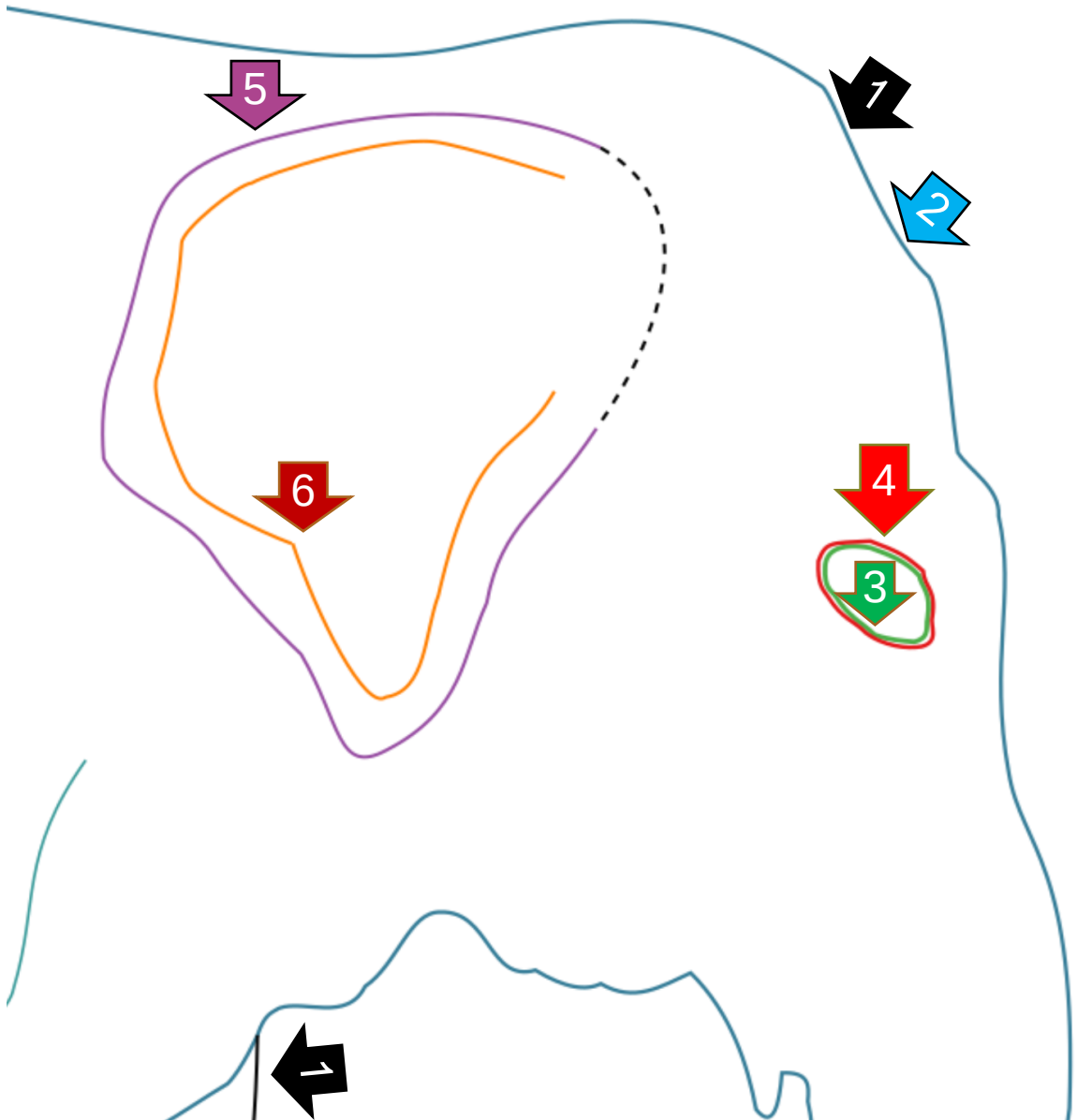


Half-edge structure from cubic Bézier curves that compose the sketches.

Represents the structural parts

- Main body
- Symmetrical parts.

Automatic Framework: Classification



Then the cycles are classified:

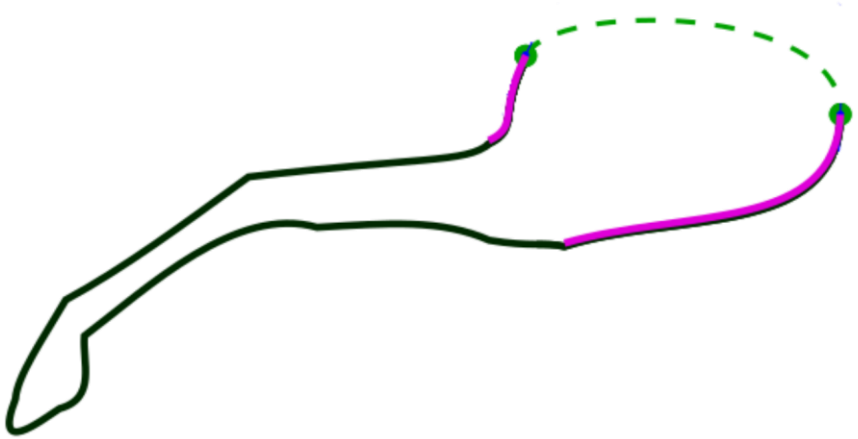
Proposed by Entem et al. (2014)

1. Outer cycle
2. Border Cycle
   - Main Body
   - Tails, nose
3. Island Cycle
   - Eyes
4. Others

Our proposed new classifications

5. Adjacent Border Cycle
6. Adjacent Feature Cycle

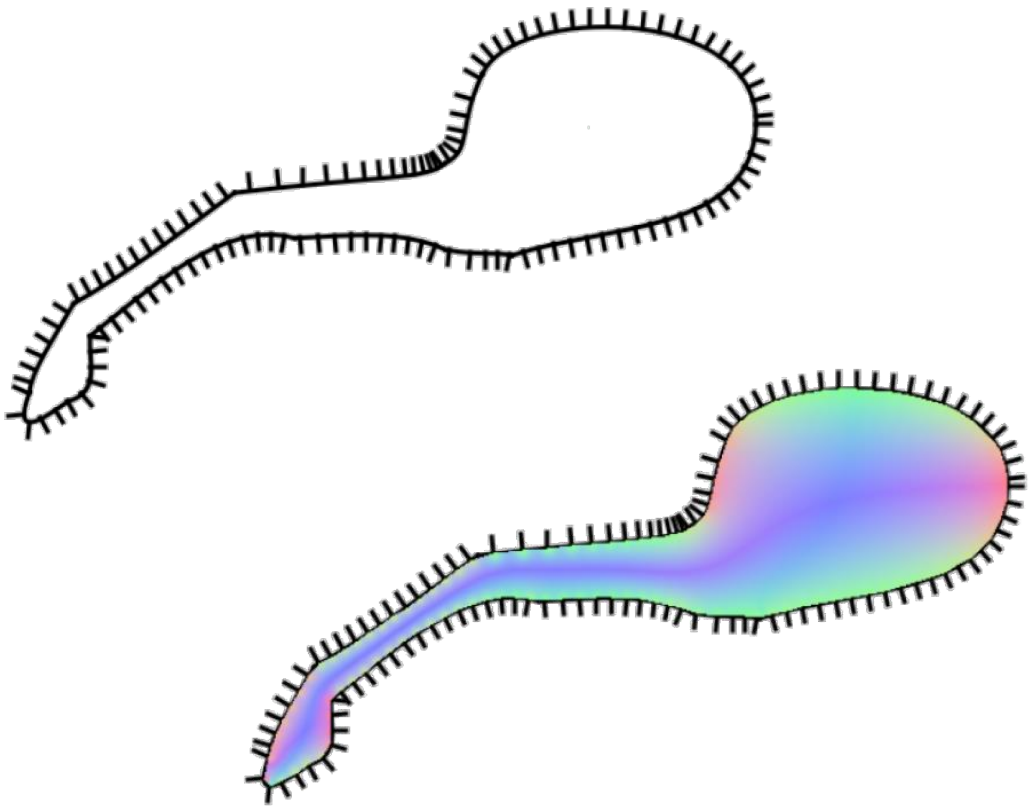
Automatic Framework: Completion



Inner-edges identify symmetric limbs

Closed by creating a new cubic Bezier between the open ends.

Automatic Framework: Hermitian Data

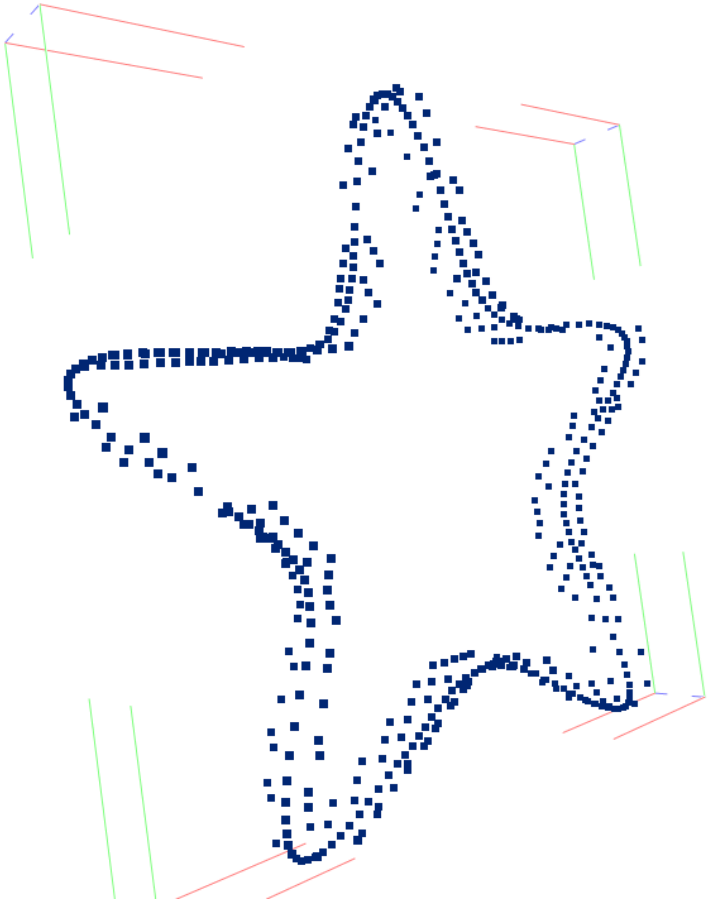


Points sampled in the contour and the corresponding normal is calculated.

From the normals of the contour, a normal field is generated within each contour.

This field is estimated by creating a grid and calculating the normals in each vertex of this grid.

Automatic Framework: Hermitian Data



Better and faster results

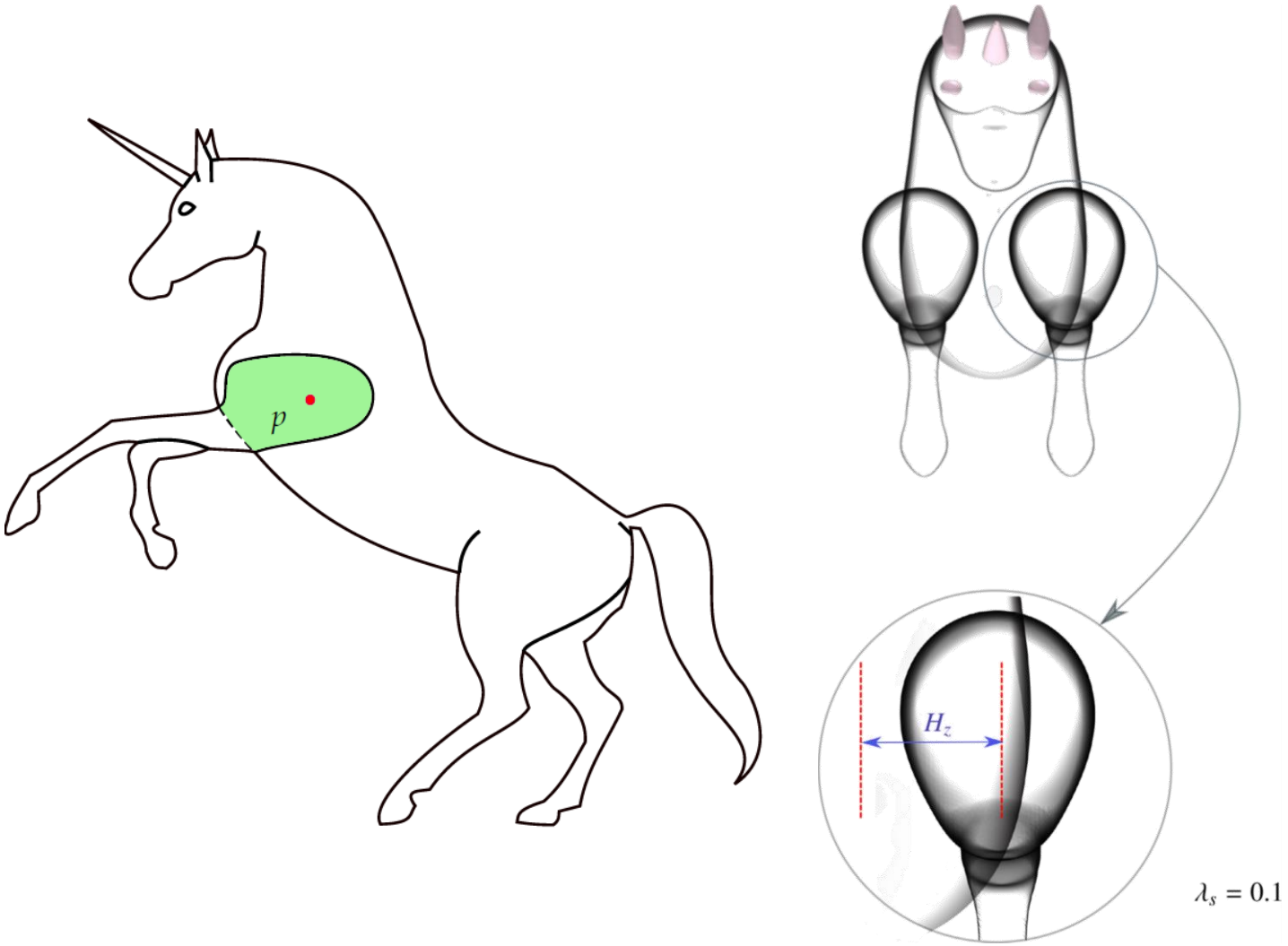
- Data near the contours
- Specifically $|n_z < 0.5|$

Depth of the points (P_z)

- Normal (n_z)
- Width of the part ($bbwidth_p$)
- Adjust $\boldsymbol{\lambda}_p$ to flatten or round shapes.

$$P_z = n_z * bbwidth_p * \boldsymbol{\lambda}_p$$

Automatic Framework: Placement



Symmetric members

- Different depth from the plane
- Replicated to the background.

Then we find the intersection of the parts and look for the point (p) that has the normal at z (n_z) of greater value in the symmetric member.

$$Hz = n_z * bbwidth_b * \boldsymbol{\lambda}_s$$

Automatic Framework: Proportion and Depth Adjustment

$\lambda_p = 0.05$
$\lambda_s = 0.025$

$\lambda_p = 0.07$
$\lambda_s = 0.05$

$\lambda_p = 0.1$
$\lambda_s = 0.1$

$\lambda_p = 0.2$
$\lambda_s = 0.125$

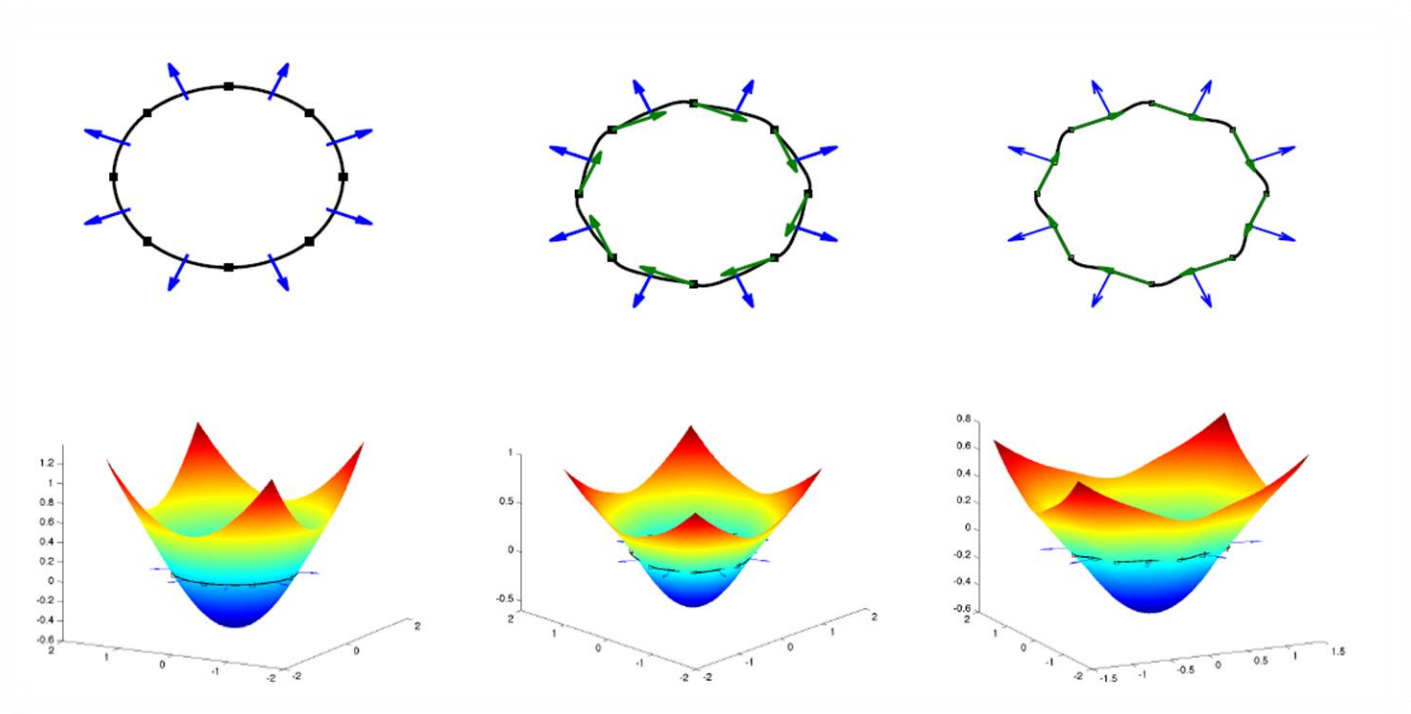
$\boldsymbol{\lambda}_p$ is used to flatten or round shapes

$\boldsymbol{\lambda}_s$ is used to adjust the depth of the parts

Automatic Framework: HRBFs

Points and normals to reconstruct each part of the sketch

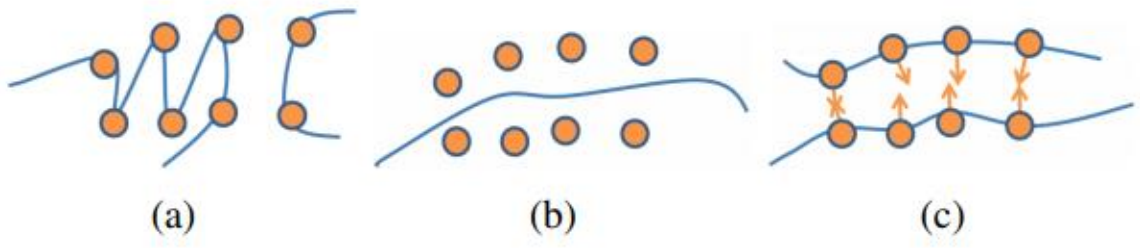
Hermite Radial Basis Functions (HRBF) are used to reconstruct implicit surfaces from generalized Hermitian data



Points
Normals
~~Tangent~~

Automatic Framework: HRBFs

The goal is to construct a function that **interpolates the set of points** considering the constraints imposed by the normals



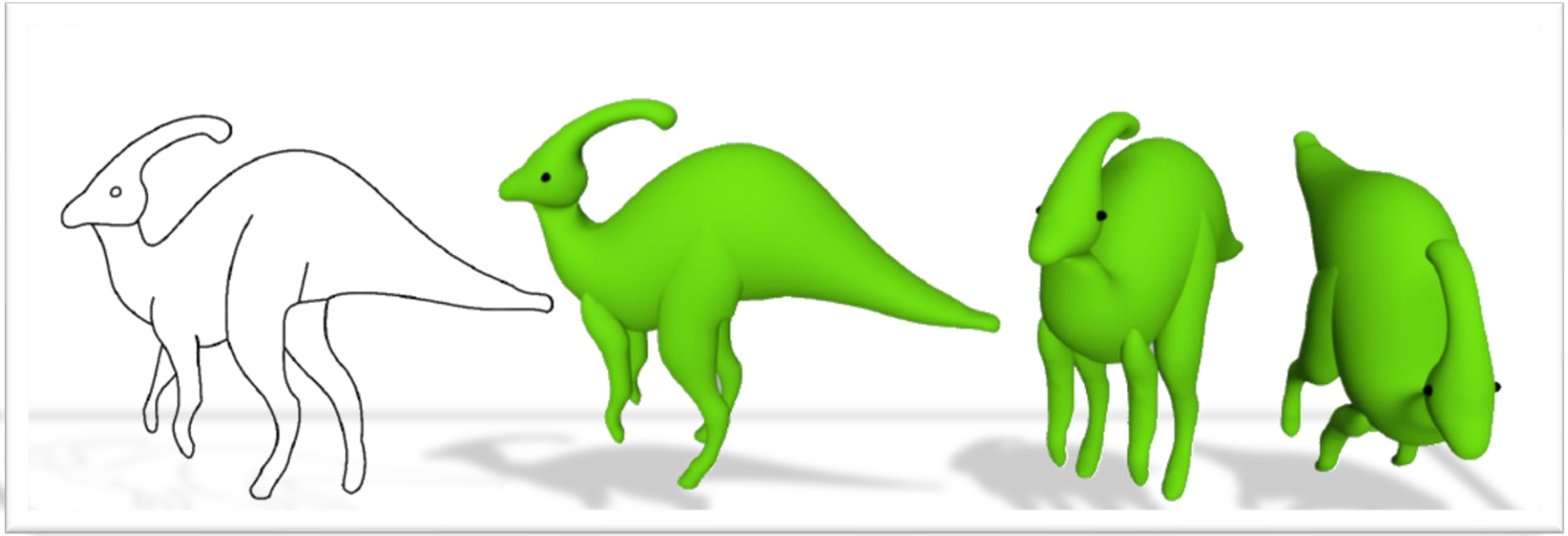
RAMLS APSS HRBF

Gois et al. (2013)

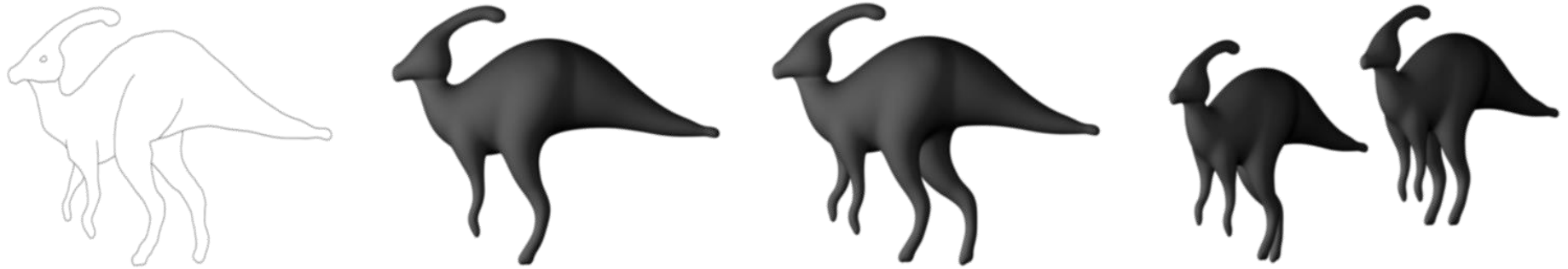
RAMLS - Robust Moving Least Squares
APSS – Algebraic Point Set Surfaces
HRBF – Hermitian Radial Basis Functions

Automatic Framework: Results

Our Approach

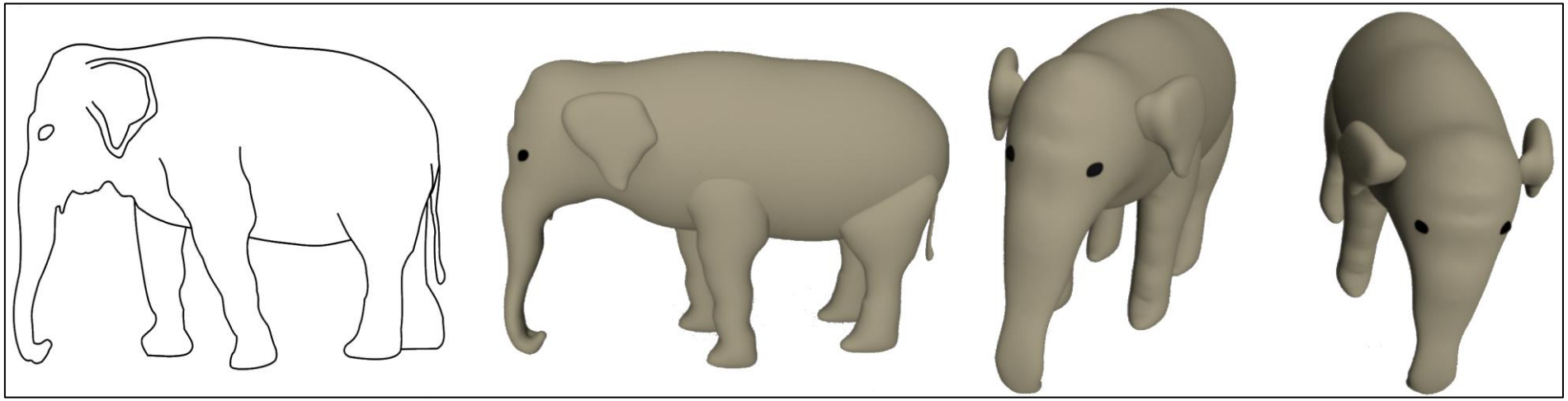


Entem et al. (2014)

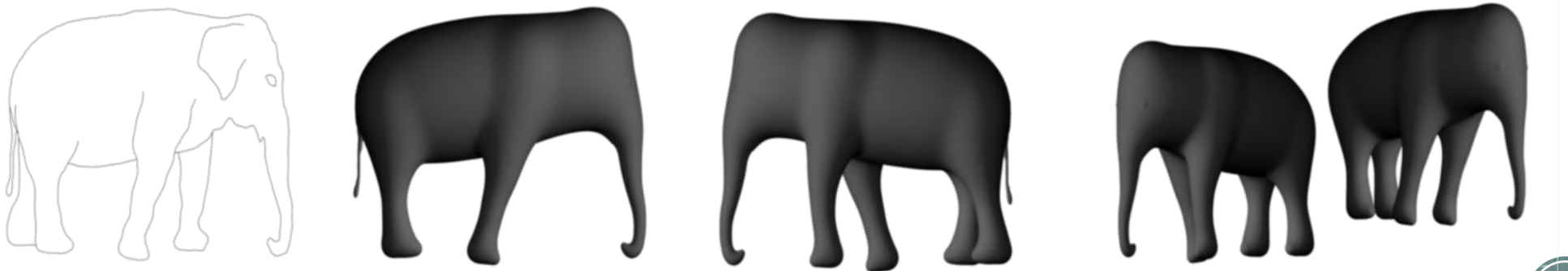


Automatic Framework: Results

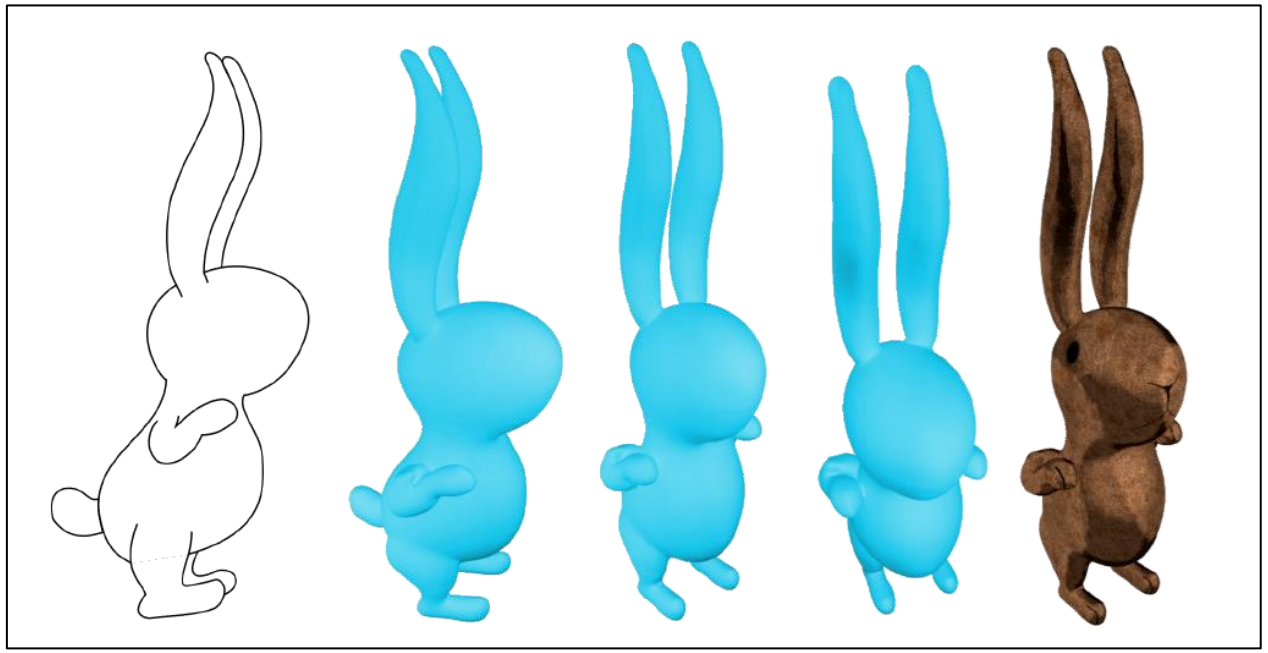
Our Approach



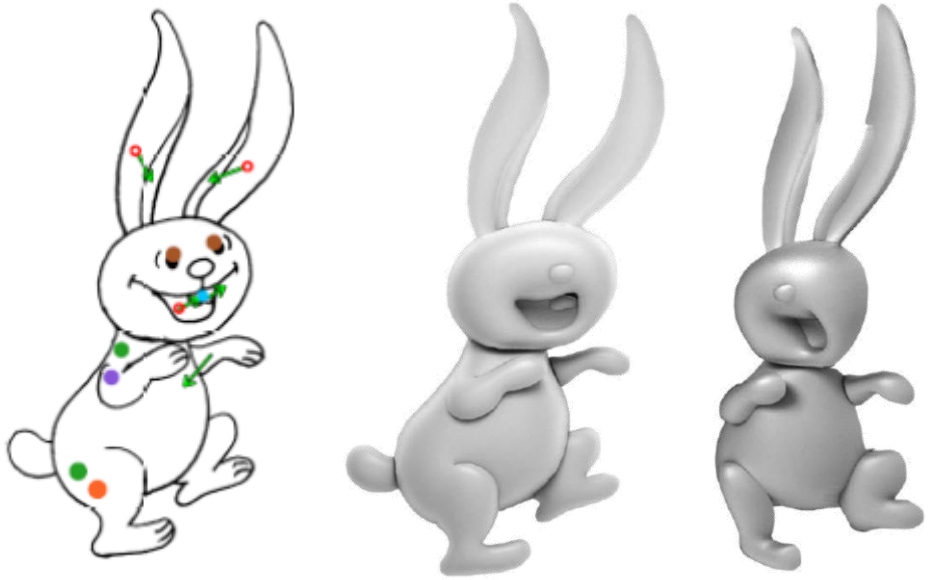
Entem et al. (2014)



Automatic Framework: Results



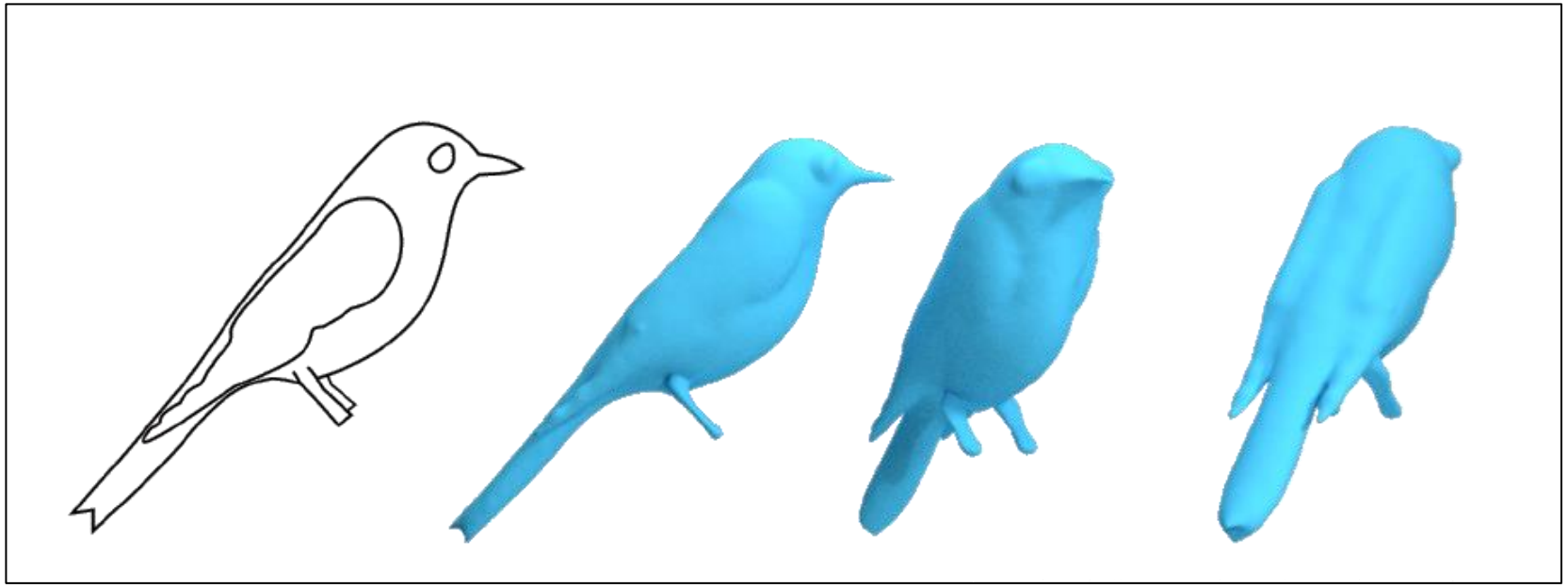
Our approach



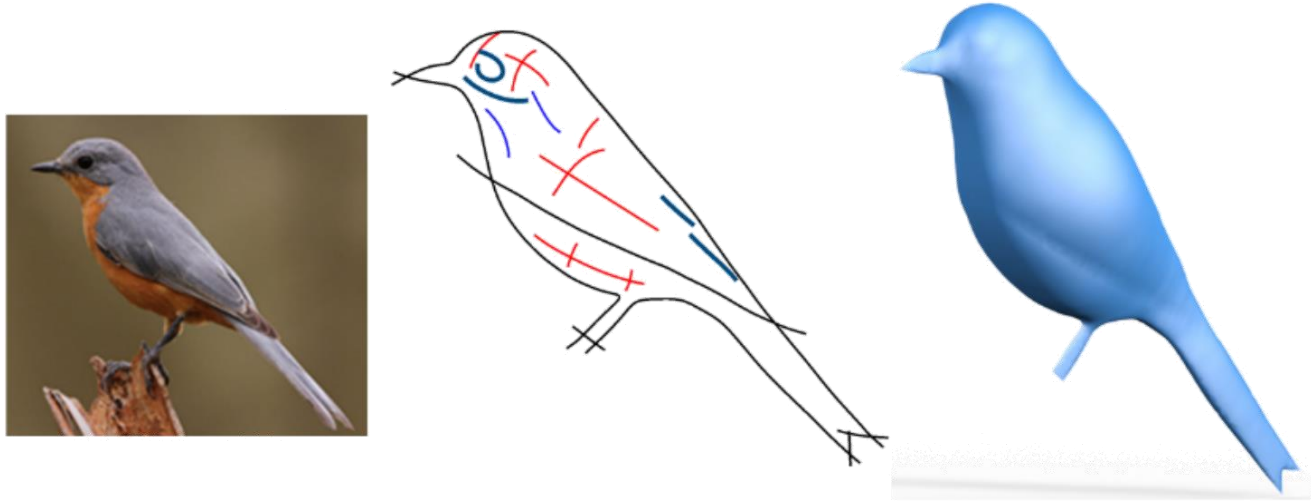
Sýkora et al. (2014)

Automatic Framework: Results

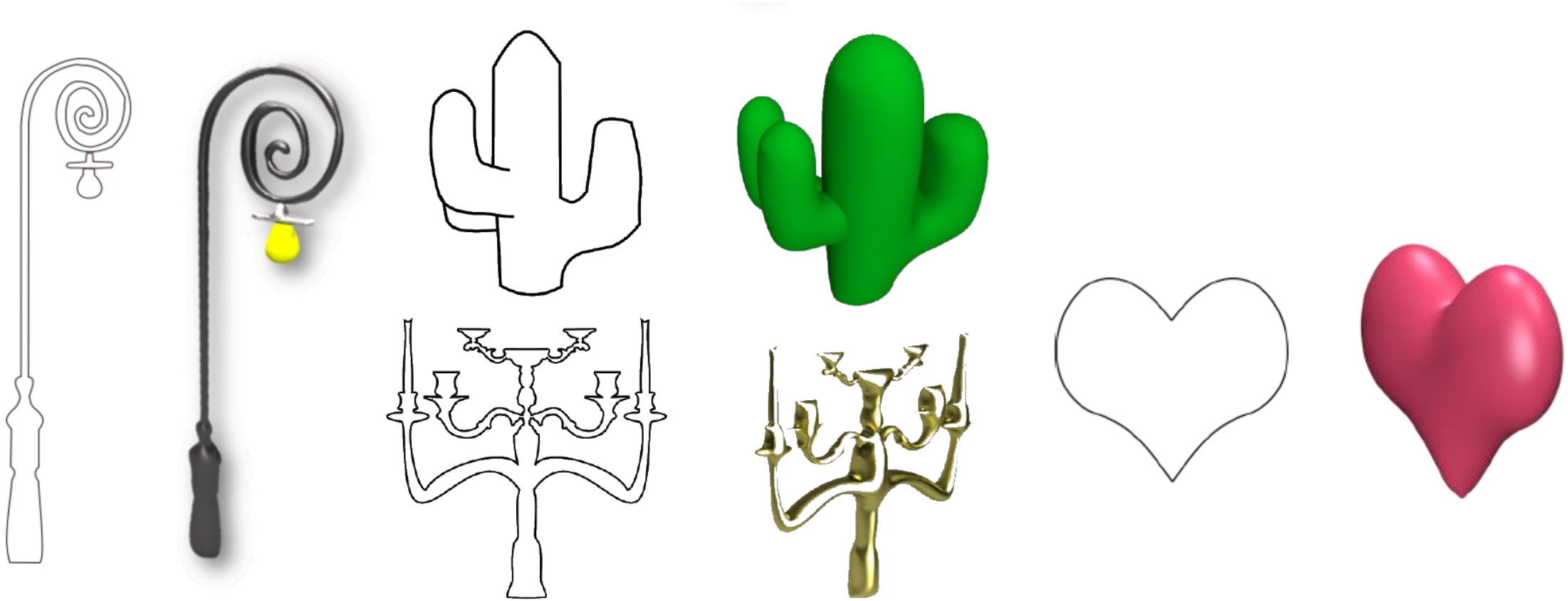
Our approach



Li et al. (2017)

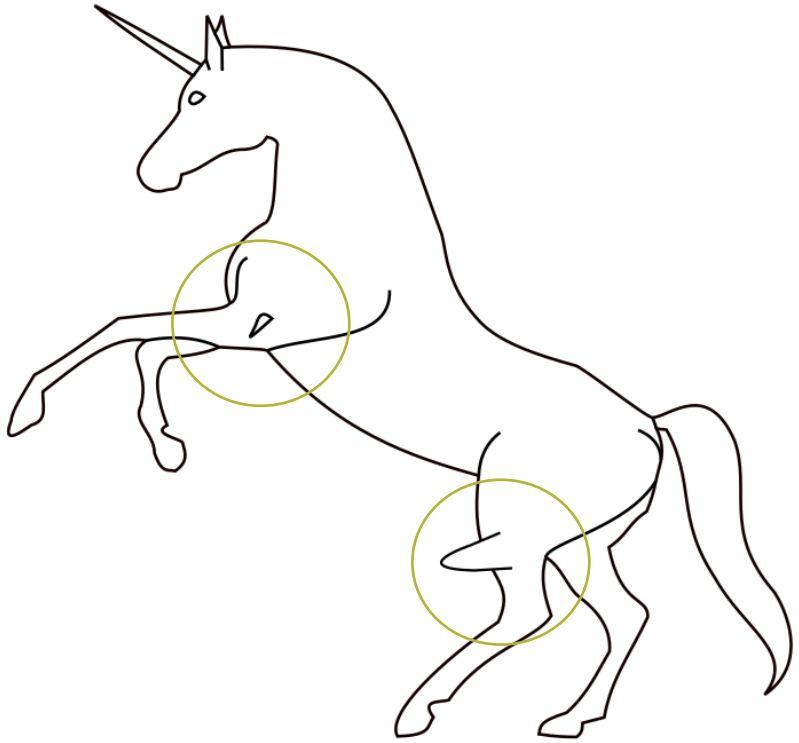


Automatic Framework: Results

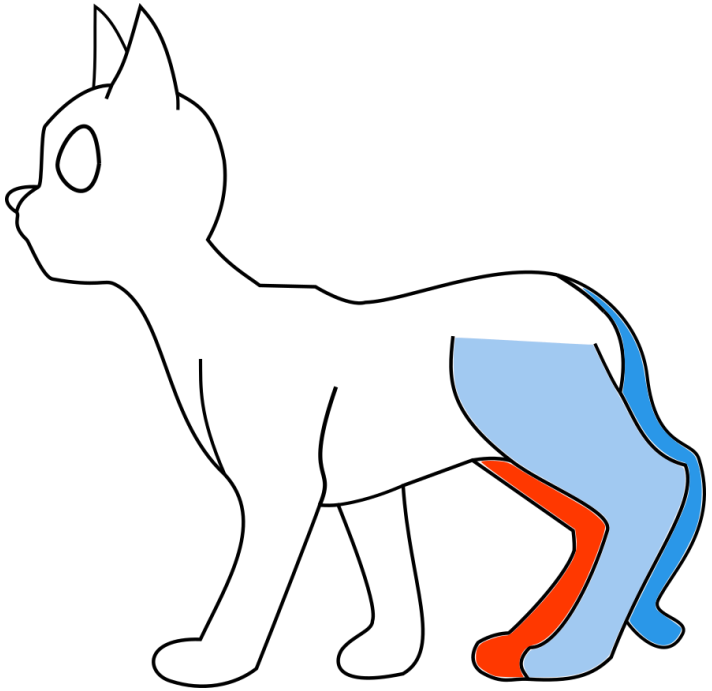


Automatic Framework: Limitations & Future Work

The proposed classification does not deal with all cases, for example, island cycles within symmetric limbs.

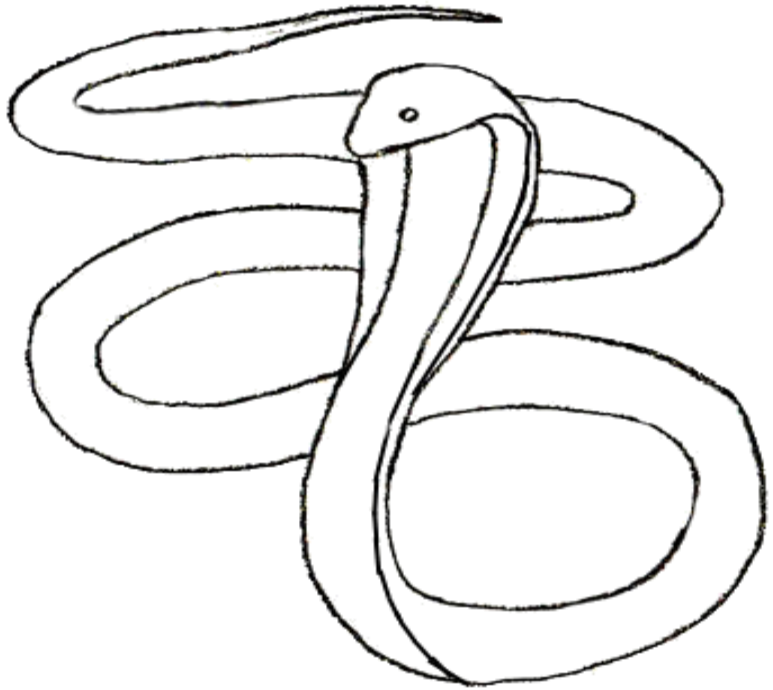


Failure case on classification

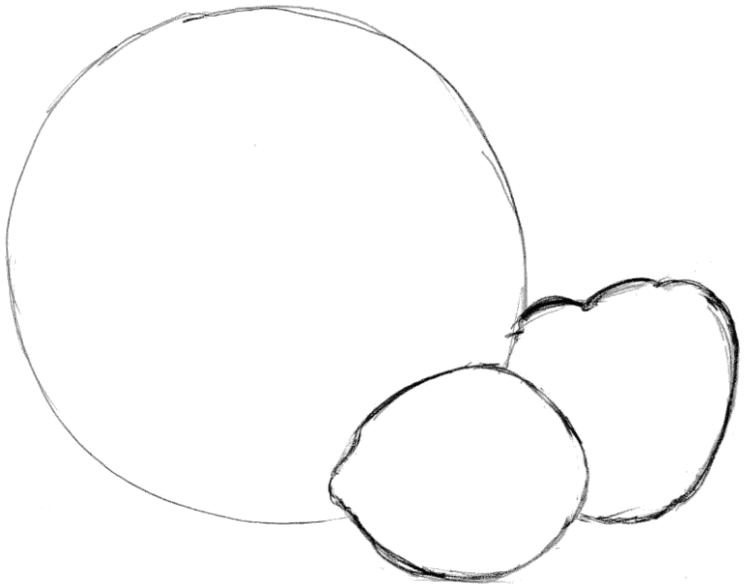


Automatic Framework: Limitations & Future Work

This method does not deal with cases in which the parts overlap.



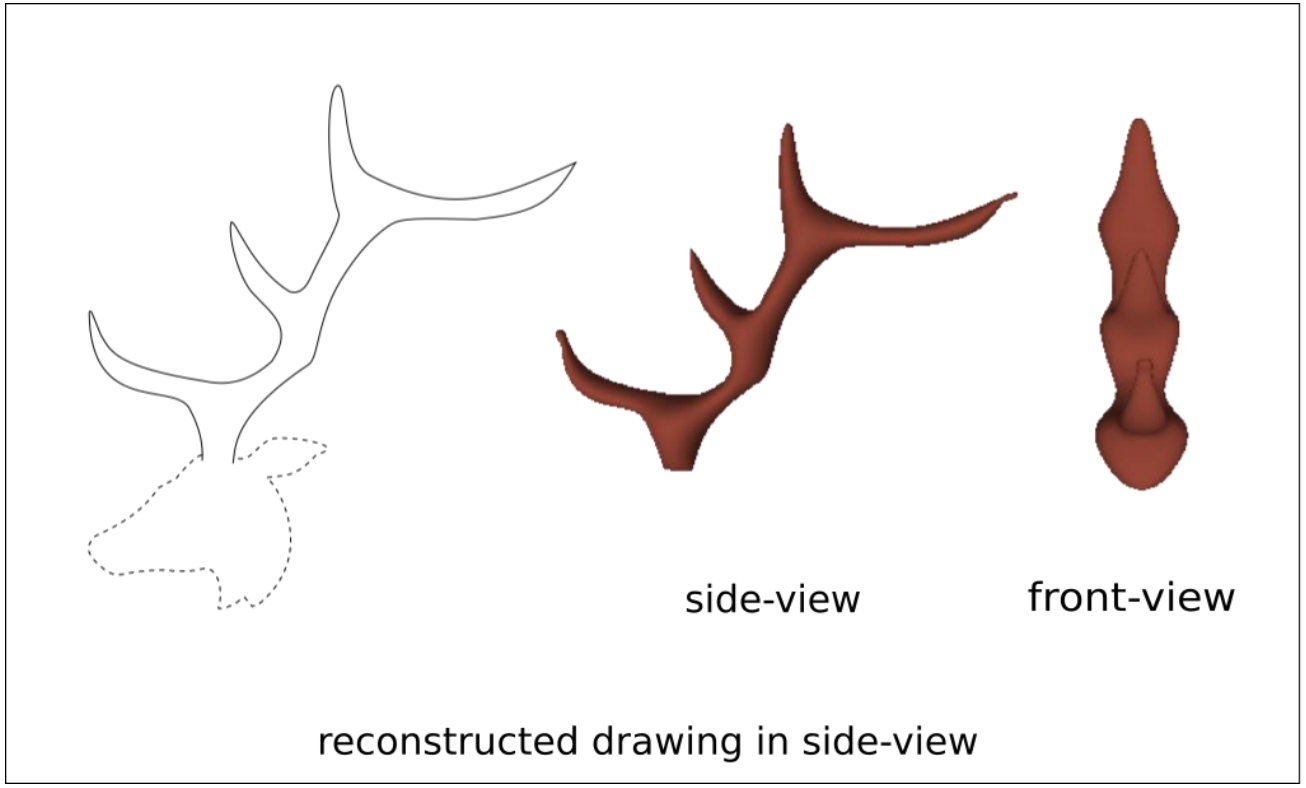
Same object

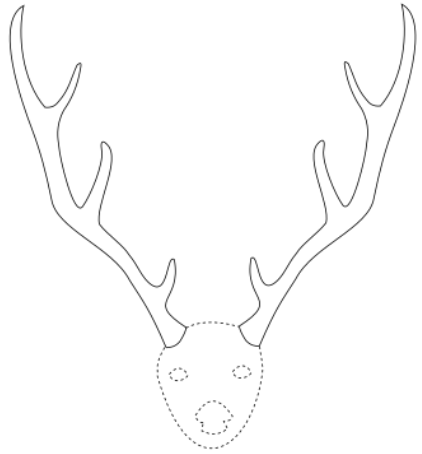


Different objects

Automatic Framework: Limitations & Future Work

This reconstruction method does not support drawings with details in other views. In case of the elk's horn, a multi-view purpose would work better.





drawing in front-view

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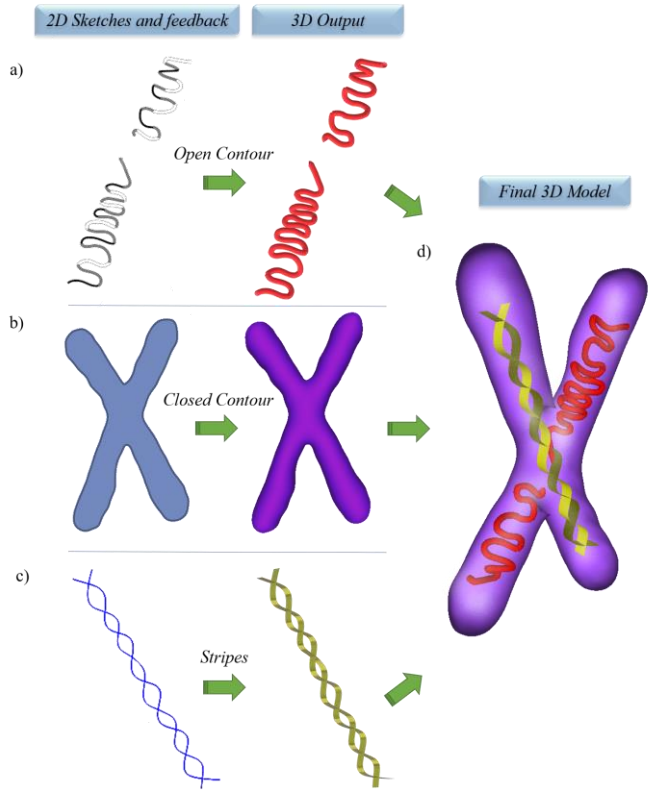
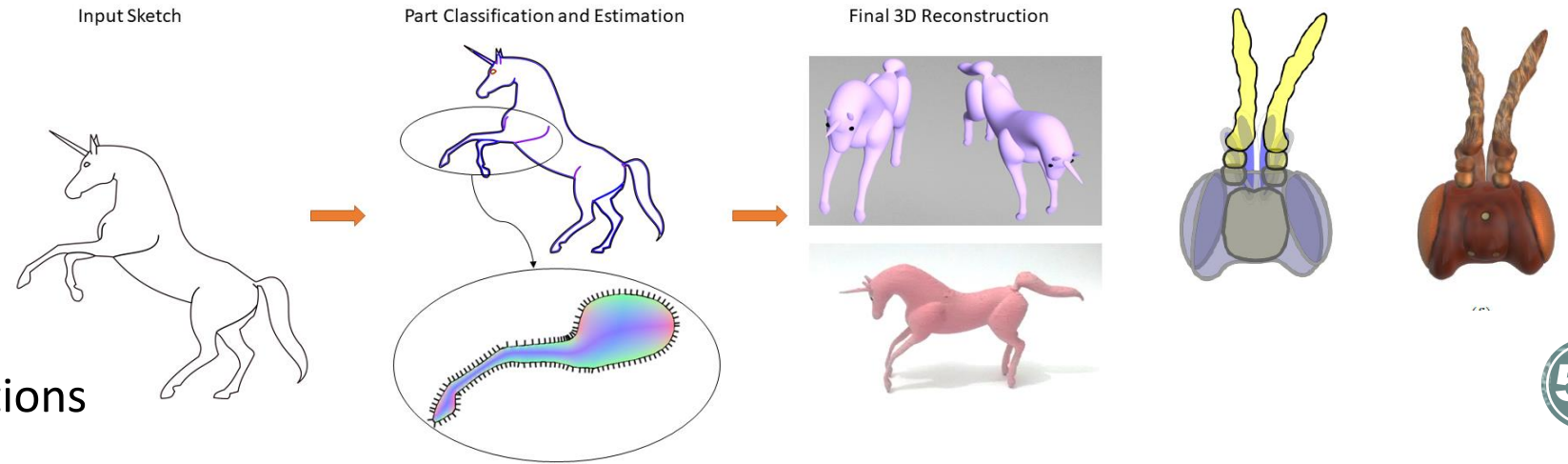
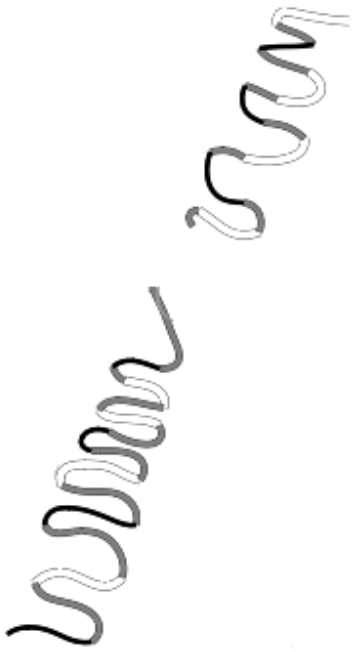
- Overview
- Automatic Framework
- **Interactive Framework**
  - Entomology Application
- Conclusions and Future Directions



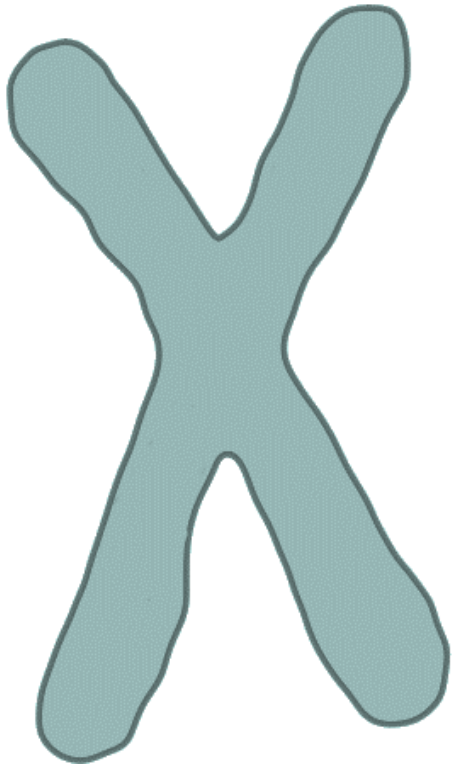


Interactive Framework

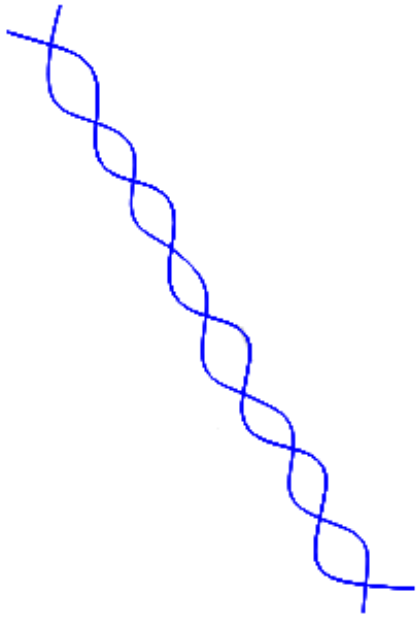
Open Contour

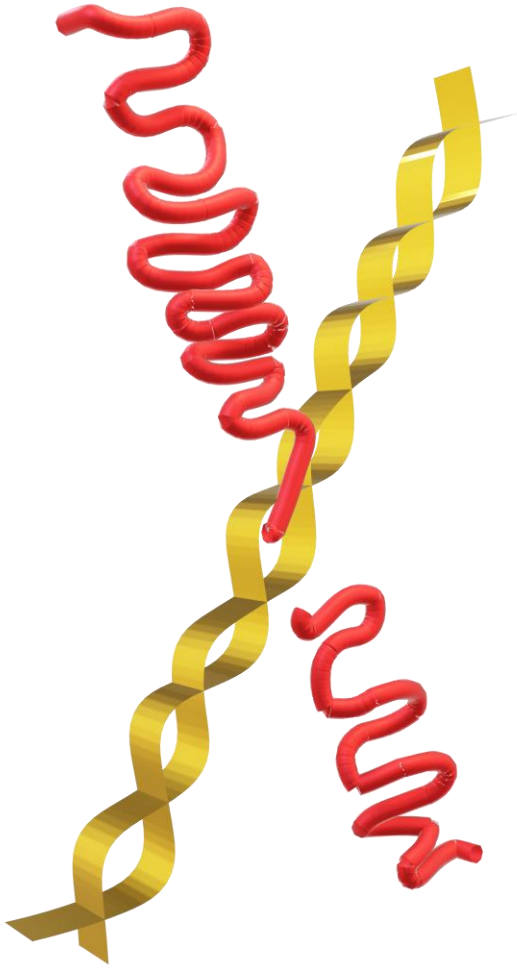


Closed Contour



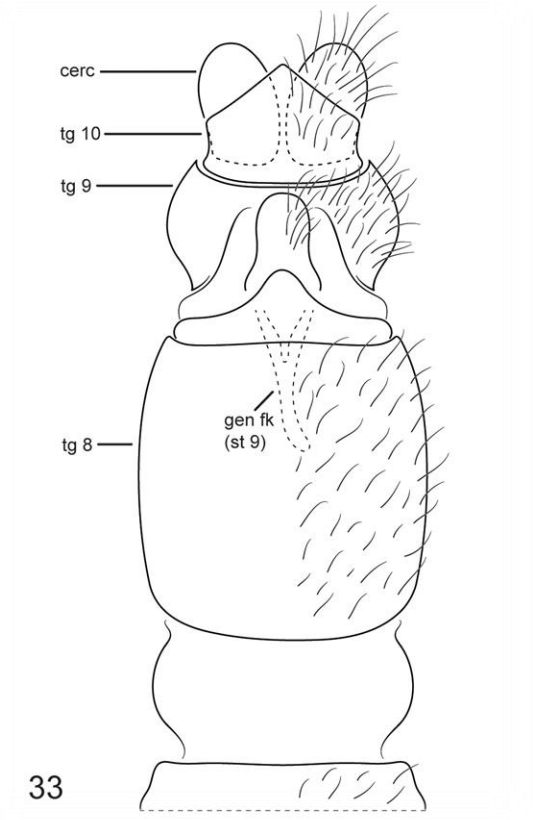
Stripes





Interactive Framework: Introduction

When dealing with artistic or scientific illustrations, the limitations shown that many sketches needs user interpretation to deal with ambiguities, layers and suggestive contours.



Fachin et al. (2018)

Burton, Mick (2015)

Laura, Maskee (2013)

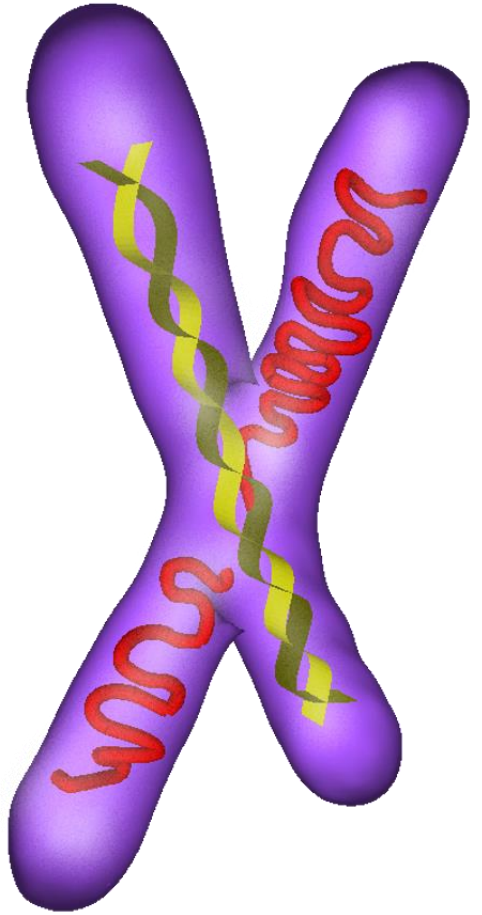
Interactive Framework: Introduction

Some essential aspects of interpretive biology still require actual drawing.

Emphasize specific parts exploring drawing elements to indicate:

- Depth
- Occlusion
- Textures
- Others

Final 3D Model



Interactive Framework: Input

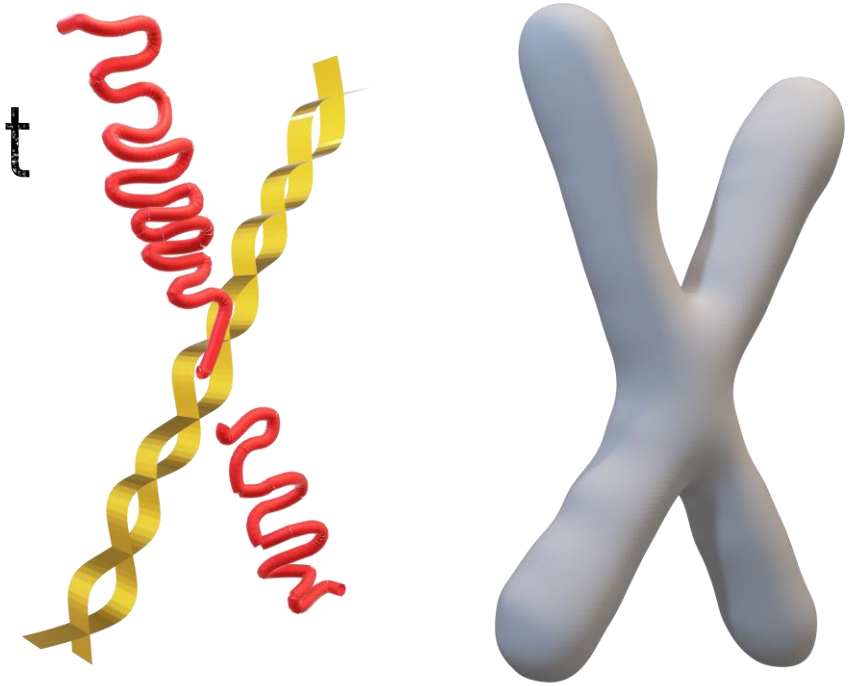
Input strokes are interactively drawn and refine through the interface.

Three categories:

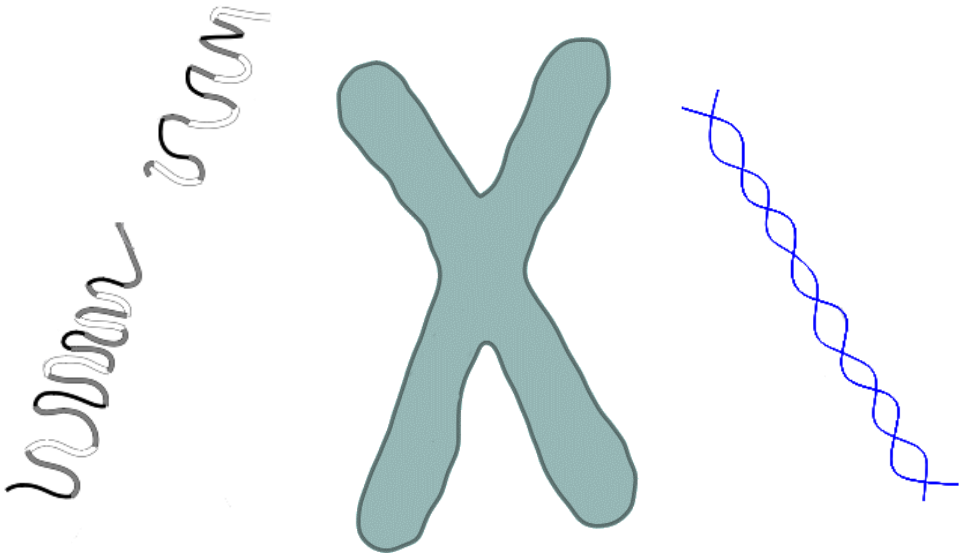
- **Open Contours**
- **Closed Contours**
- **Stripes**

Differs in their 2D visual enhancements and 3D reconstruction.

Scalable Vectorial Graphics (SVG) files can be used for **Closed Contours**



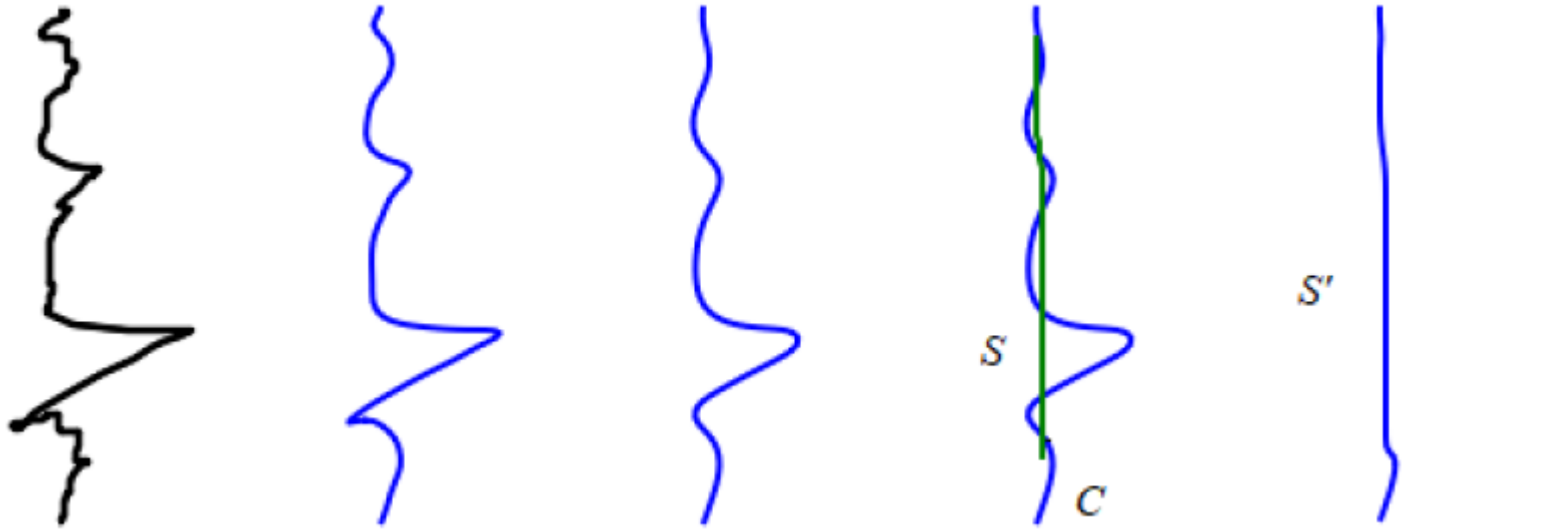
Open Contour *Closed Contour* *Stripes*



Interactive Framework: Creation Phase

Support for contour refinements

- **Smoothing**
  - Reverse Chaikin scheme
  - Samavati and Bartels (2004)
- **Oversketching**
  - Vital Brazil et al. (2010)



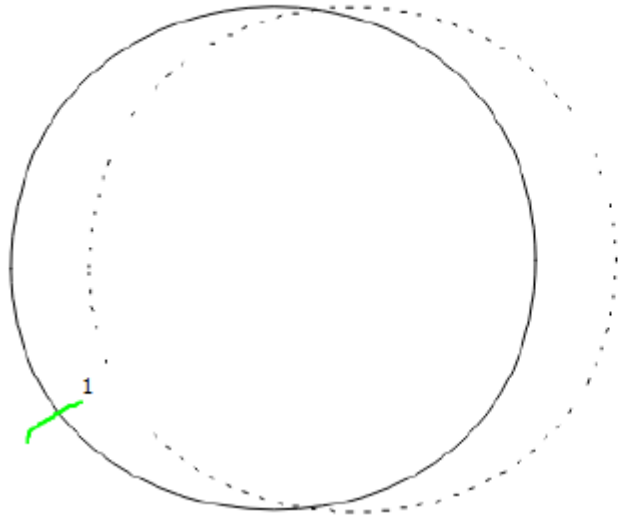
Raw Stroke | Smoothing 3x | Smoothing 9x | Oversketching Curve | Resulting Curve

Interactive Framework: Creation Phase

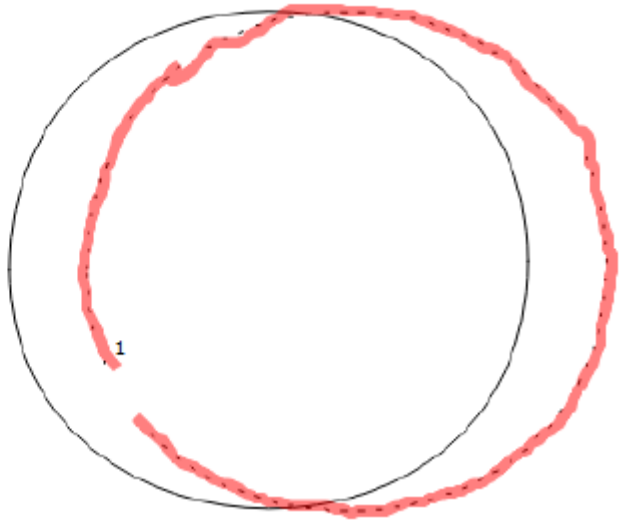
Besides the **sketching, smoothing** and **oversketching.**

Closed contours can be selected in SVG files

- Cross Selection
- Brush Selection
- Erase Selection (Similar to Cross)



Cross Selection



Brush Selection

Strokes selected describe closed contours

Create new curves that connects

- Extremities
- Line Segments

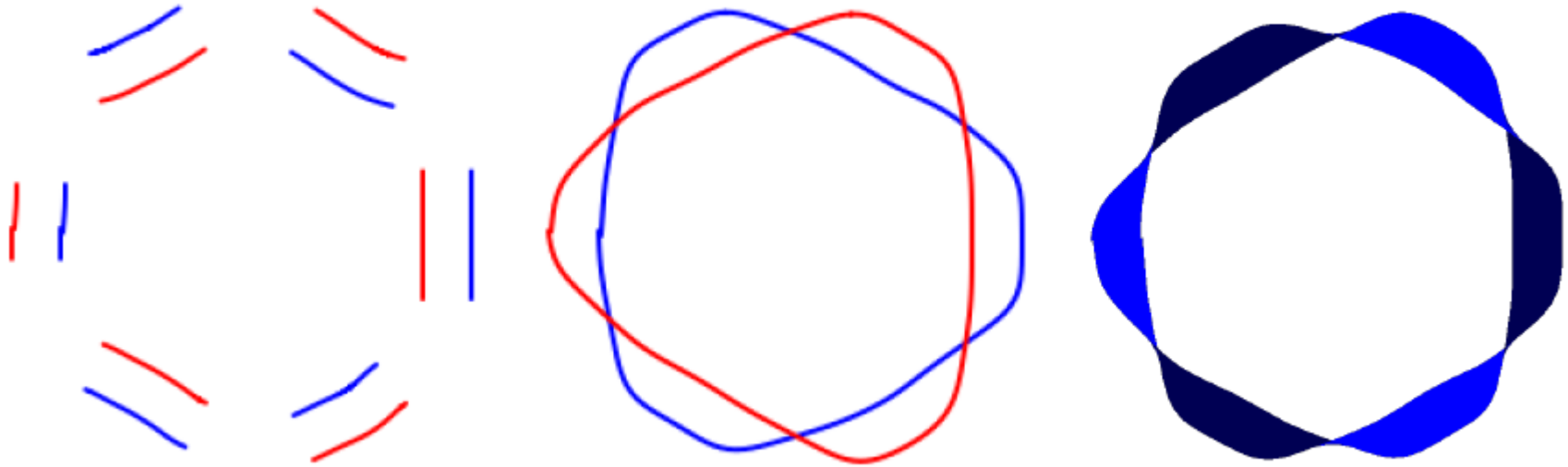
Interactive Framework: Creation Phase

Guidelines following the stripe silhouette in two colors, blue and red.

Ä twist is created by **releasing** the mouse button and **starting** again the drawing

A **right click** finishes the construction of the stripe.

Stripes



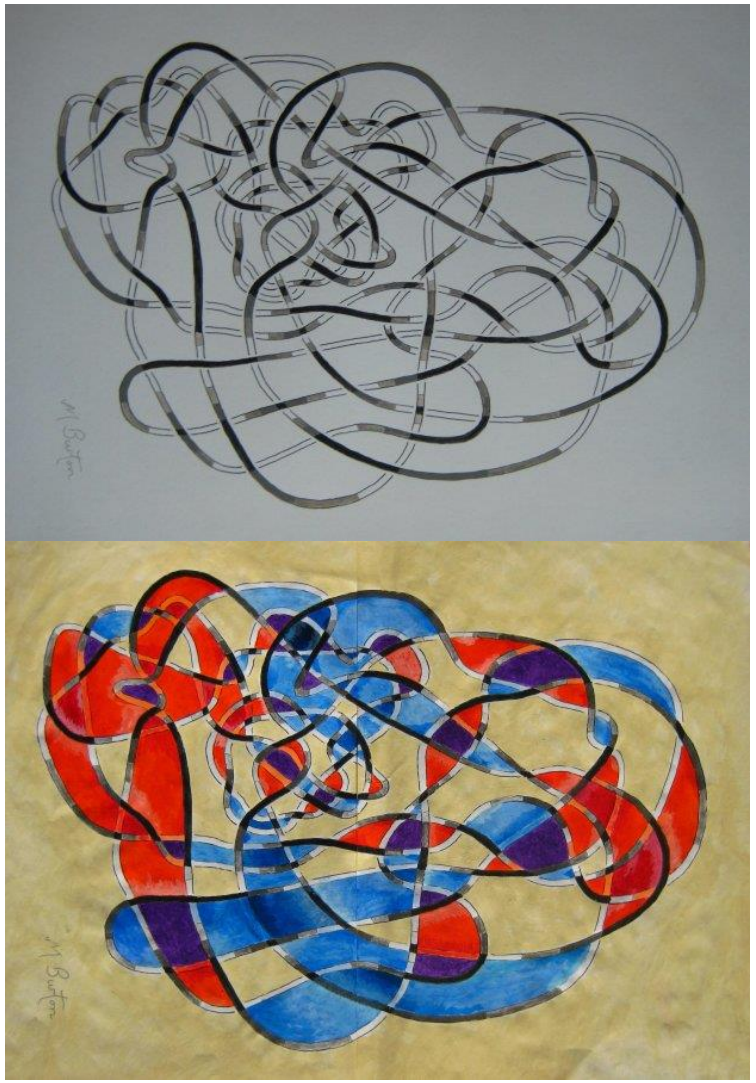
Interactive Framework: Visual Enhancements

We consider layers as features of sketches

Every **open contour, closed contour** and **stripe** are addressed to a layer

Effects are applied to enhance visual feedback

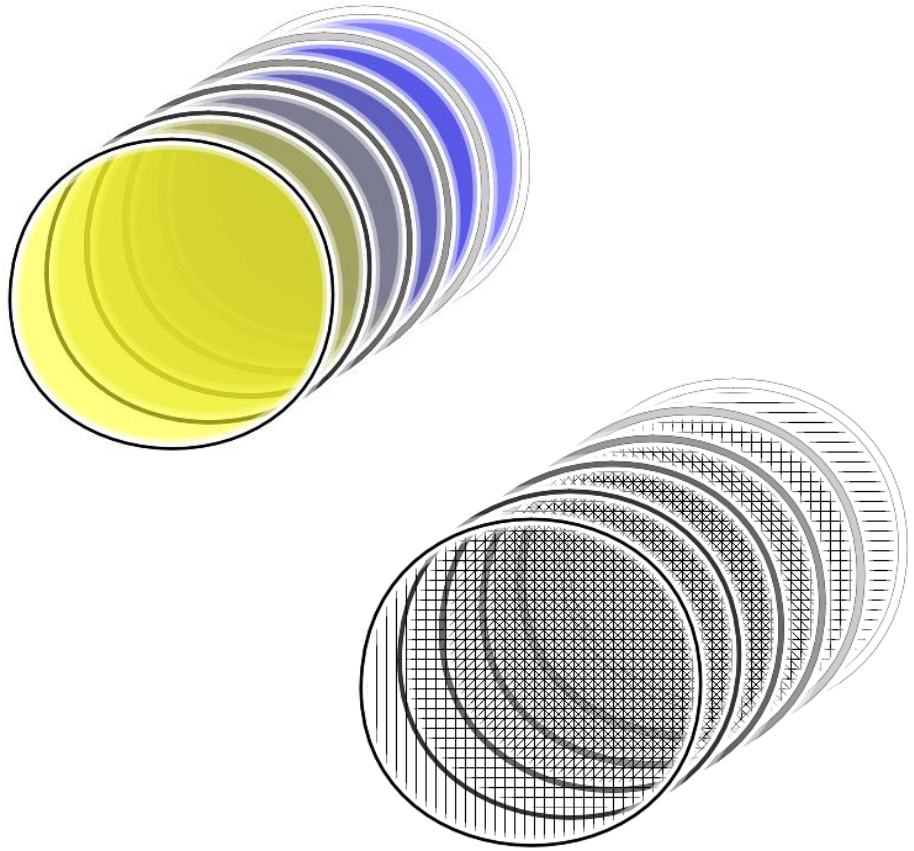
We guided our visual effects using principles of human visual perception found in traditional illustration and NPR [30, 119, 103, 61, 23].



Continuous Line Drawings. Burton, Mick (2015)

Interactive Framework: Visual Enhancements

- **Color map** and **transparency** to depict layers
- Depiction of areas using **hatching lines**.
- **Depth-dependent halos** to increase the depth perception of overlapping lines
- **Tone-based** emphasizing of contours

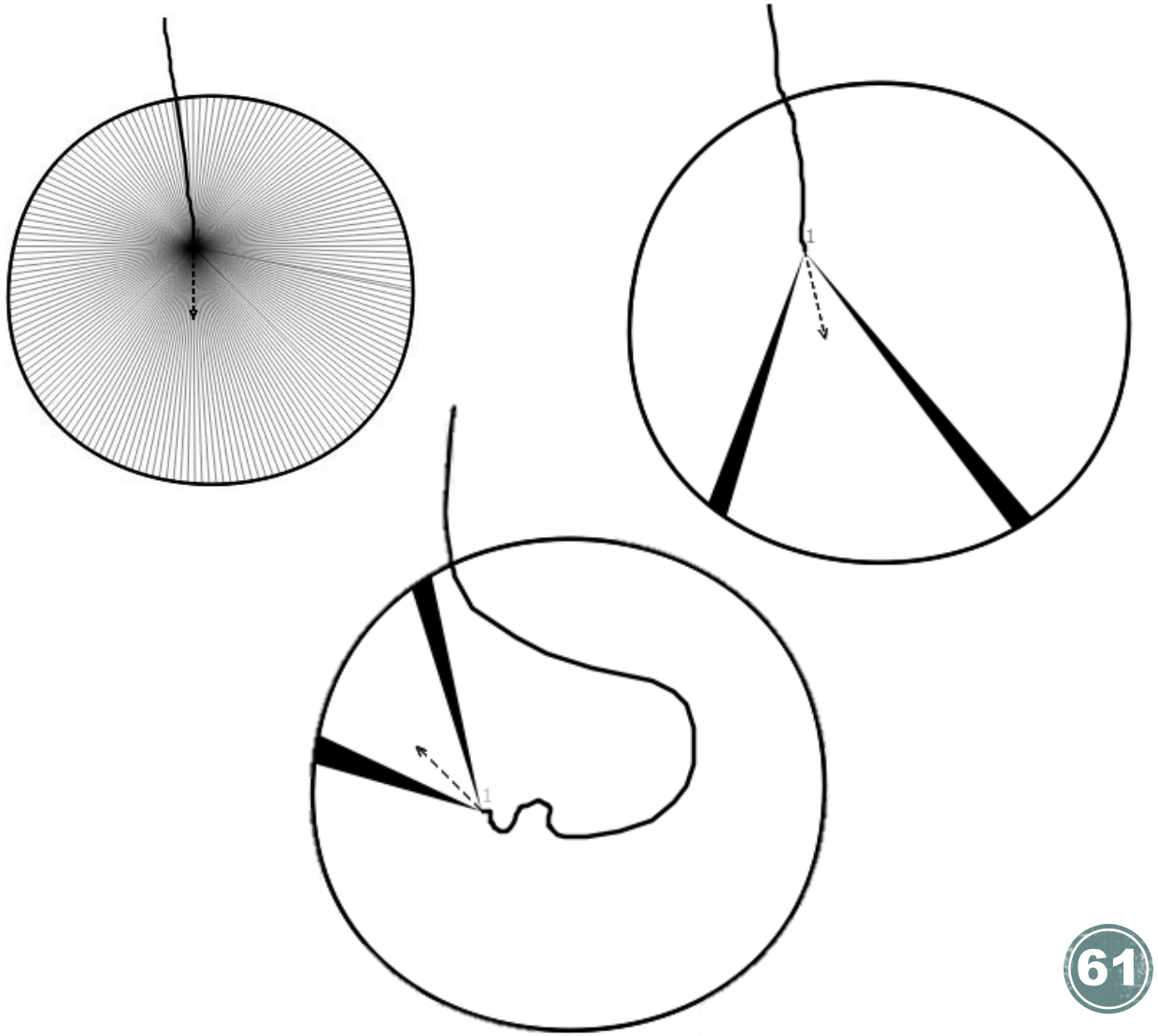


Interactive Framework: Visual Enhancements

Sketch inference for closed contours to indicate overlays

While sketching new strokes

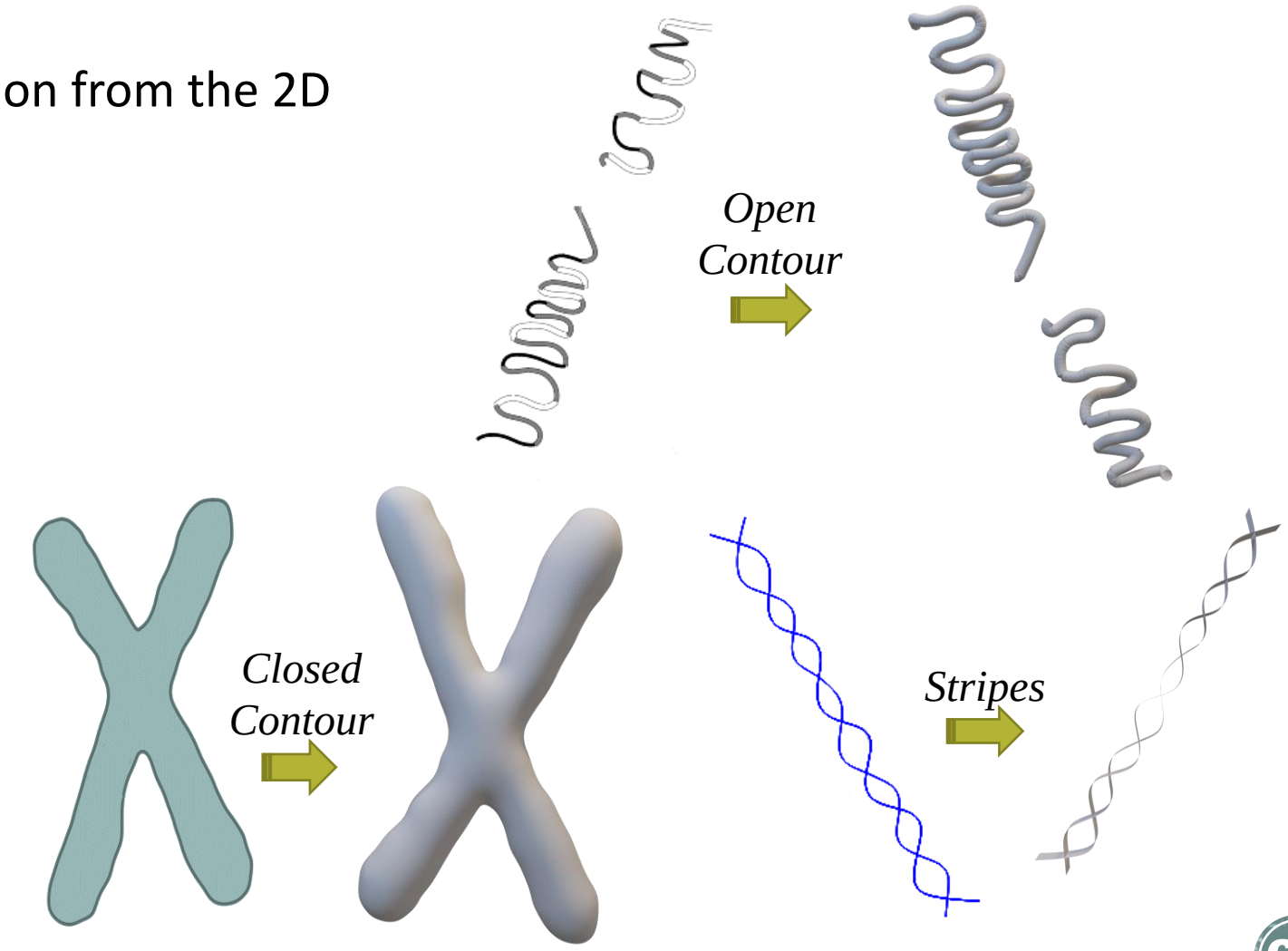
We paint a set of triangles according to their angle with the sketching line.



Interactive Framework: 3D Reconstruction Phase

Our system creates a 3D representation from the 2D contours considering:

1. Category
2. Silhouette
3. Addressed layer.

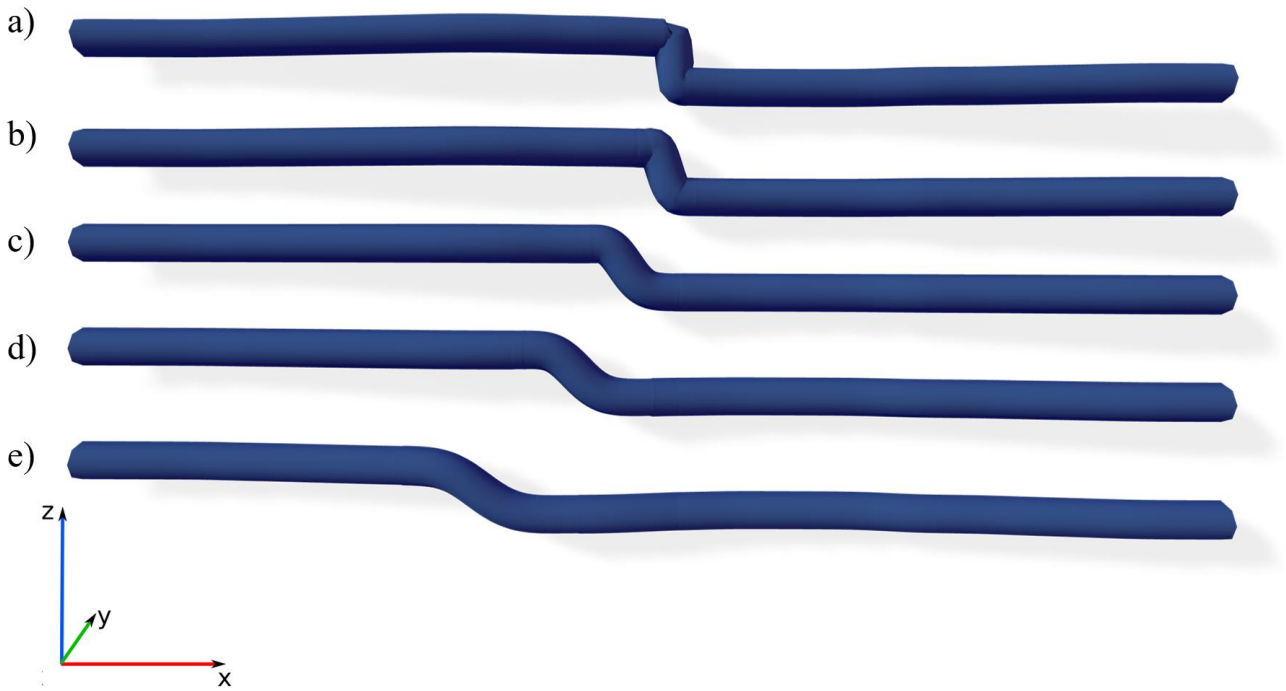


Interactive Framework: 3D Reconstruction Phase

Open Contours are reconstructed by creating 3D cylinders

Now for 3D reconstruction, only points on z-axis are considered for smoothing.

There are no points between the layers at the first smoothing operation.



Smoothing operations applied to z-axis of an open contour (a) one time, (b) ten times, (c) fifty times, (d) one hundred times and, (e) two hundred times

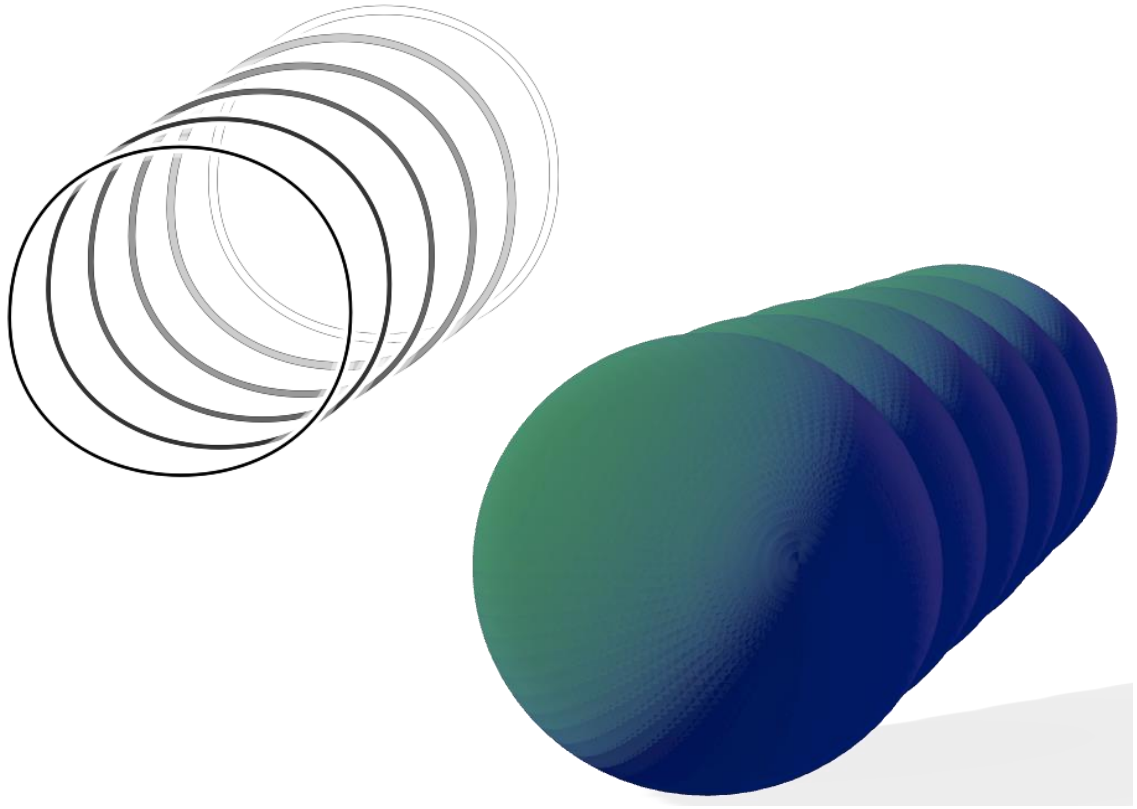
Interactive Framework: 3D Reconstruction Phase

Closed contours describe 3D surfaces, it means that these contours forms closed loops and do not intersect themselves.

Models are reconstructed as desired:

- Rotational Blending Surface
  - Cherlin et al. (2005)

- Hermite-RBF Surfaces reconstruction
  - Gois et al. (2013) & Ramos et al. (2018).



Rotational Blending Surfaces

Interactive Framework: 3D Reconstruction Phase

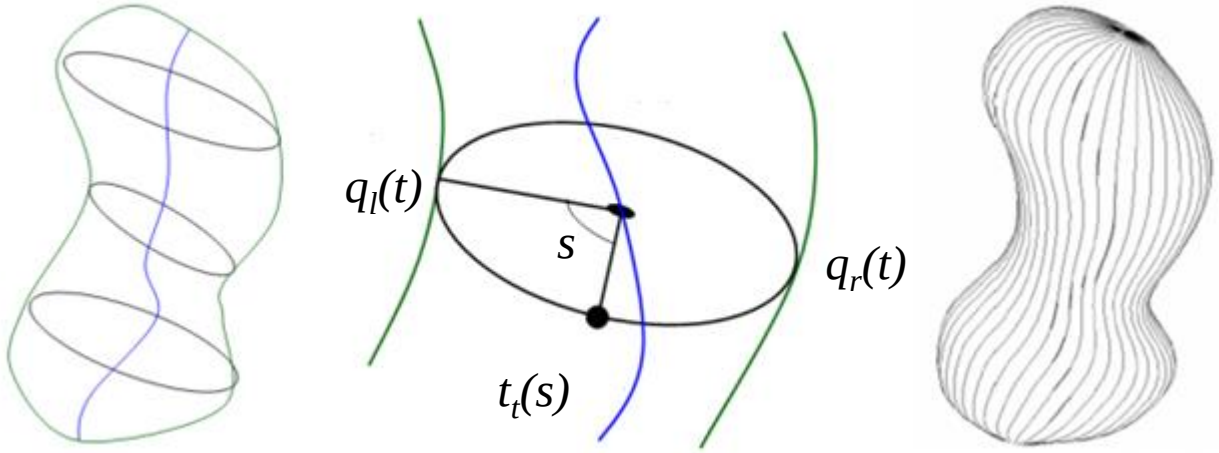
Sample pairs of points on strokes to create a medial axis.

The framework allows to rotate the medial axis

Parametrize a circle perpendicularly

- Center $c(t)$
- Containing the points $q_l(t)$ and $q_r(t)$

Create the 3D mesh with points sampled in $t_t(s)$



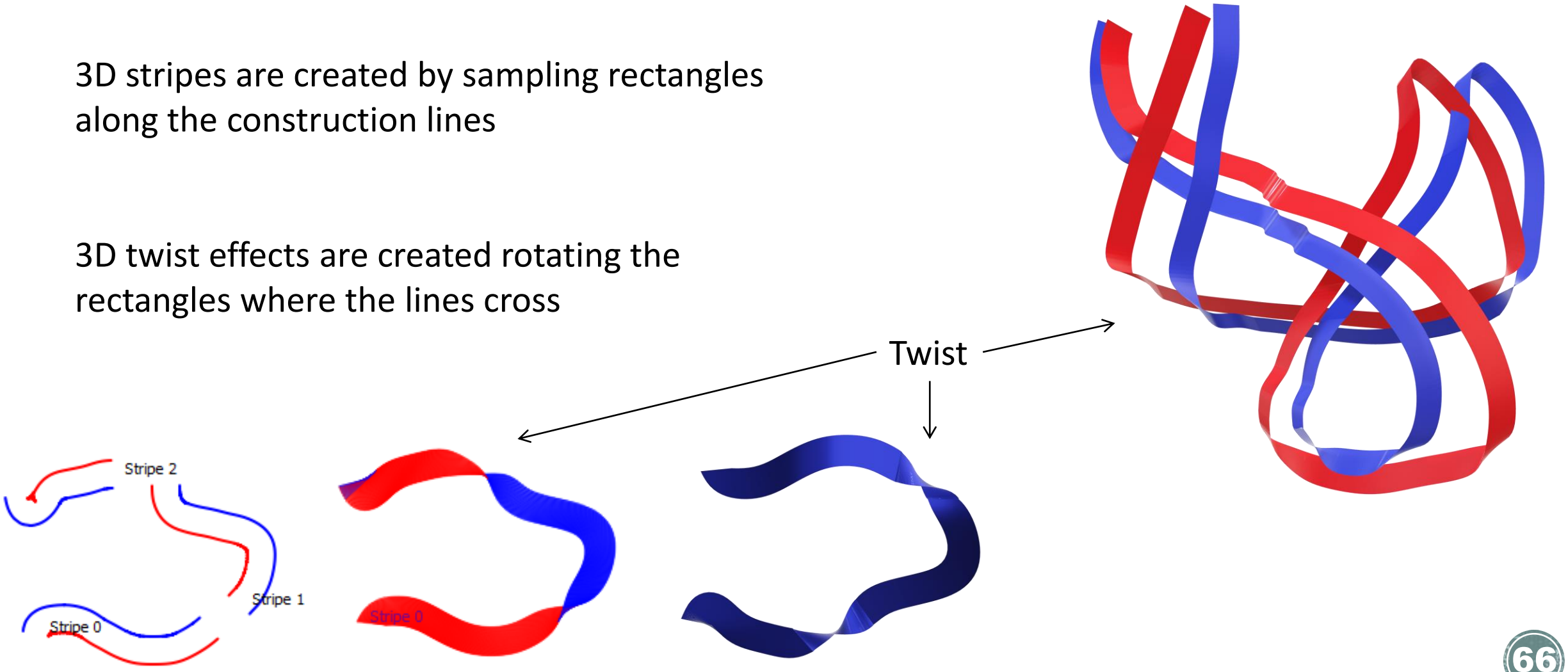
Rotational Blending Surfaces Reconstruction

Cherlin et al. (2005)

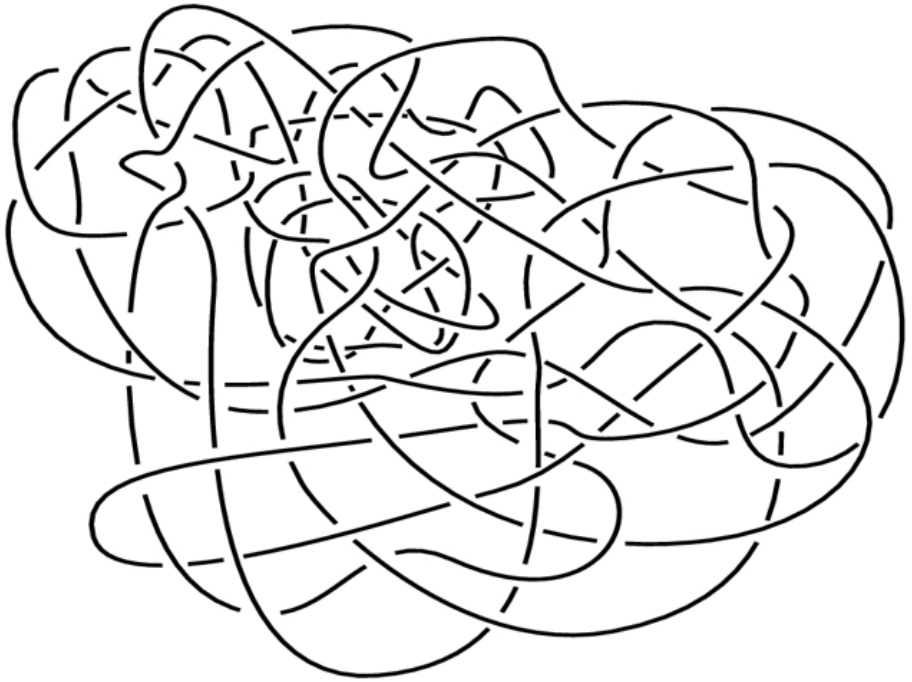
Interactive Framework: 3D Reconstruction Phase

3D stripes are created by sampling rectangles along the construction lines

3D twist effects are created rotating the rectangles where the lines cross



Interactive Framework: Results



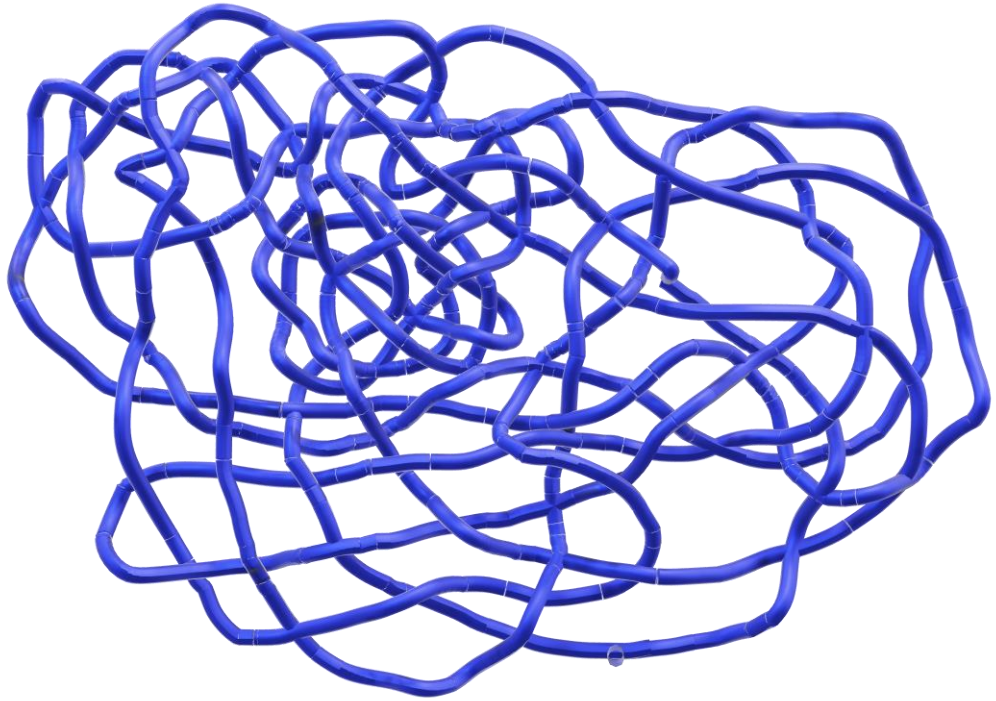
a) Haken's Gordian Knot
Adapted from Fish and Lisitsa (2014)

b) Mick Burton Interpretations (2015)

We created and evaluated drawings containing overlaying objects.

Interactive Framework: Results

b) Our sketch traced over the images

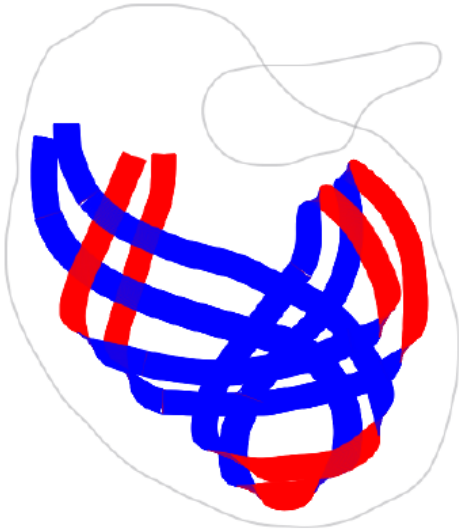


c) Resulting 3D Model

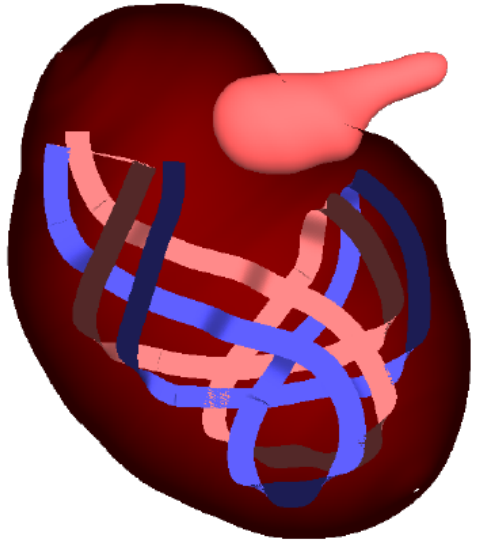
Interactive Framework: Results

a) Original image
Maskee, Laura (2013)

b) Vectorized drawing

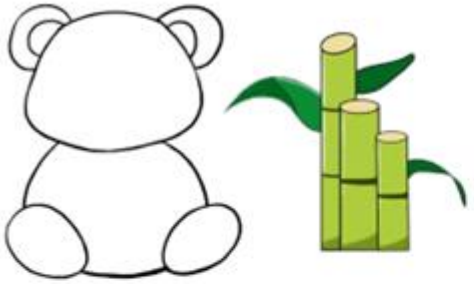


c) Our sketch over the drawing

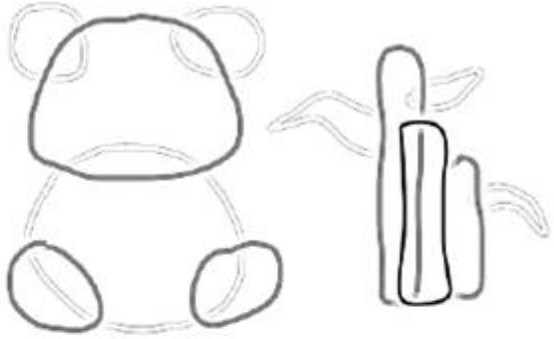


d) 3D resulting model

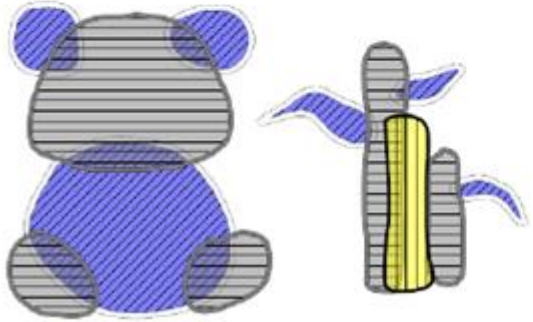
Interactive Framework: Results



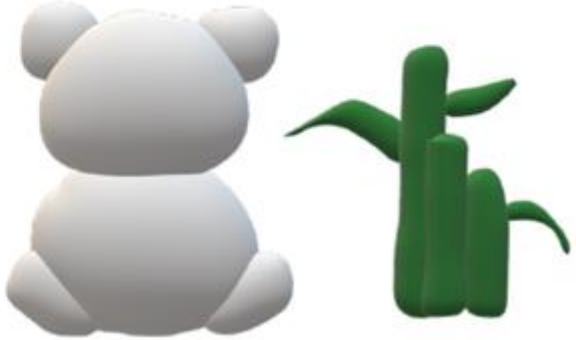
Drawing



Contour and Halo



Coloring and Hatching



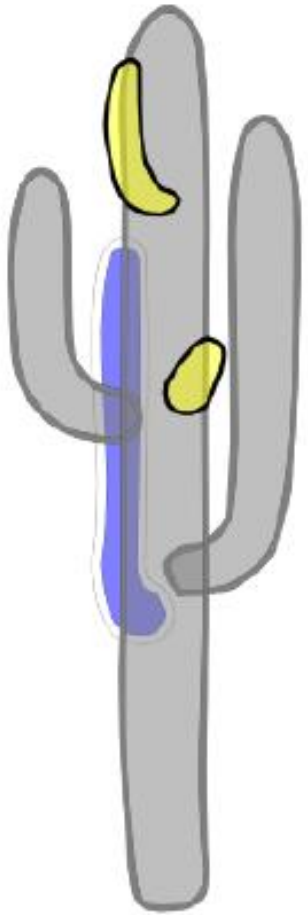
3D Model

Hermite-RBFs

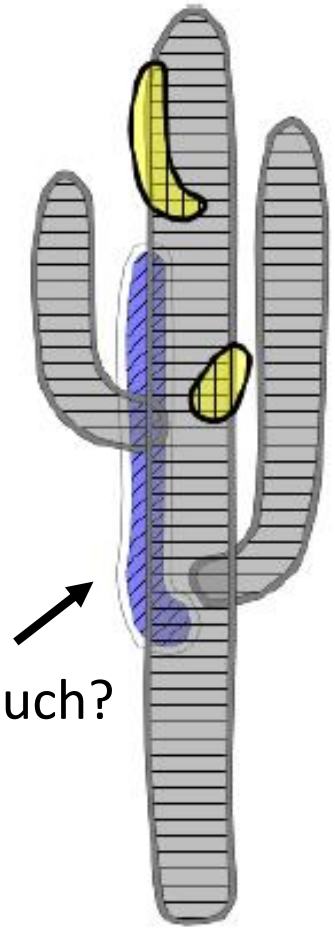
Rotational Blending Surface

Texturized 3D Model

Interactive Framework: Results



Contour Shading
Layer Coloring



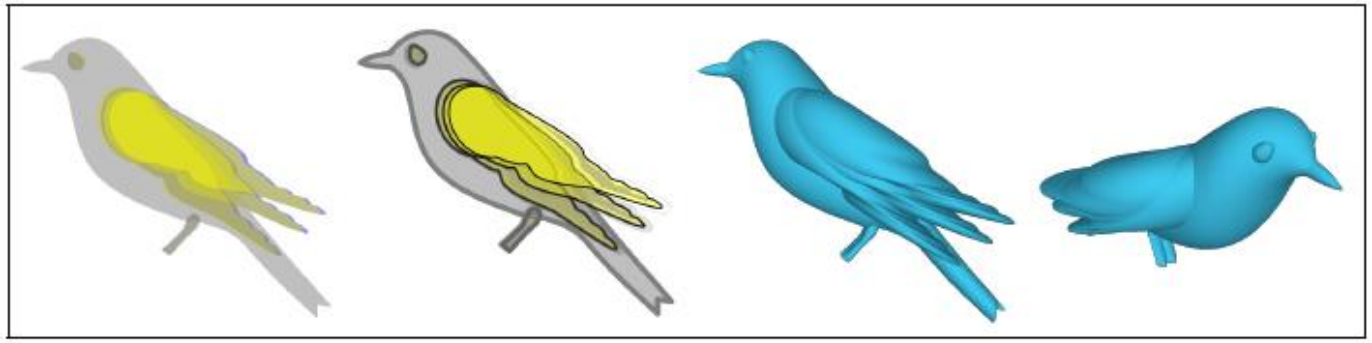
Contour Shading
Layer Coloring
Hatching Effect

3D Model

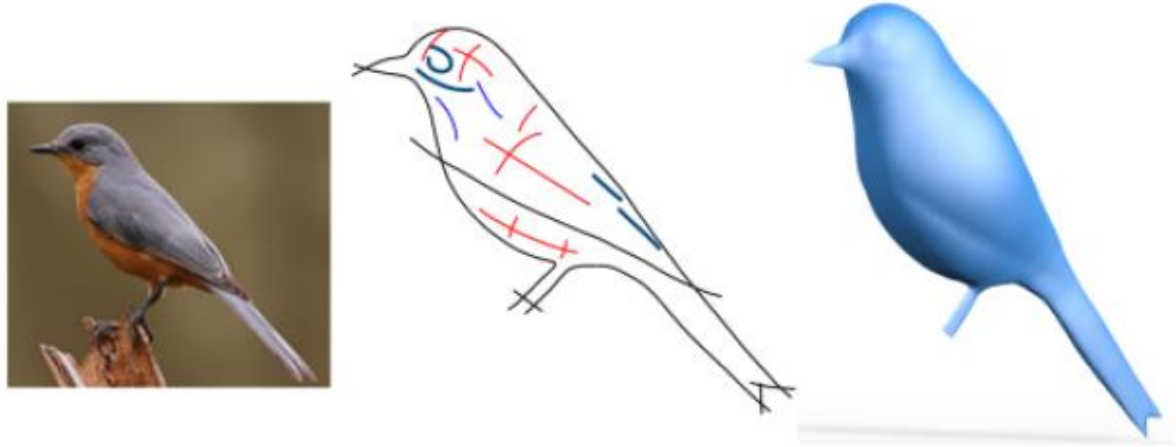
Texturized 3D Model

Interactive Framework: Results

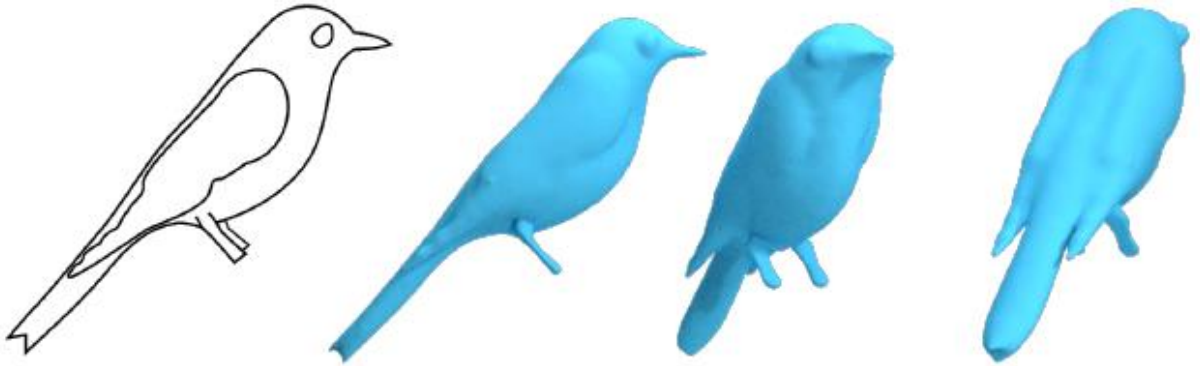
Our Approach



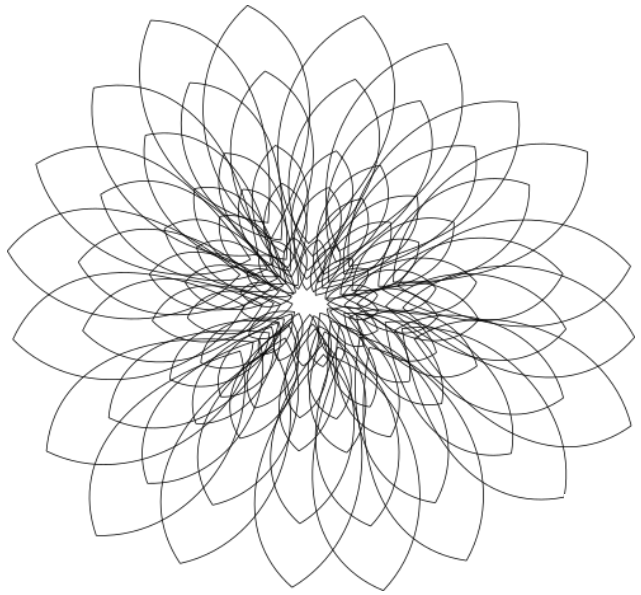
Li et al. (2017)



Ramos et al. (2018)

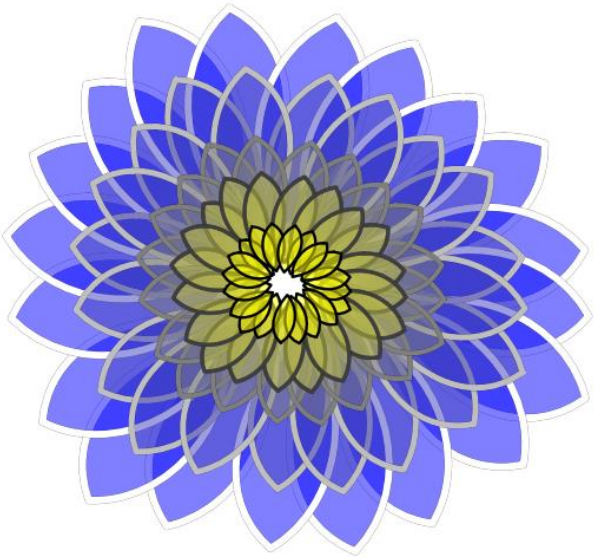


Interactive Framework: Results



a)

Multiple Contours and Layers



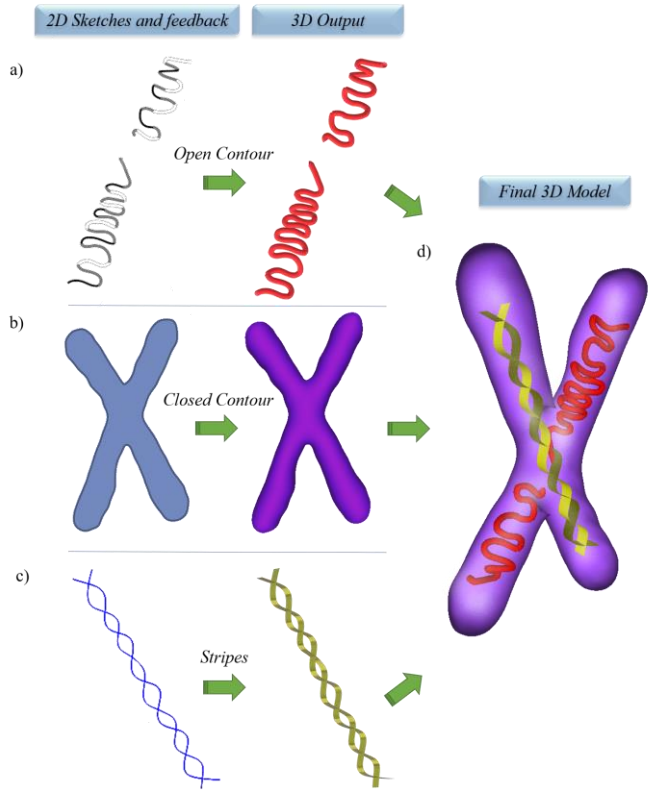
b)

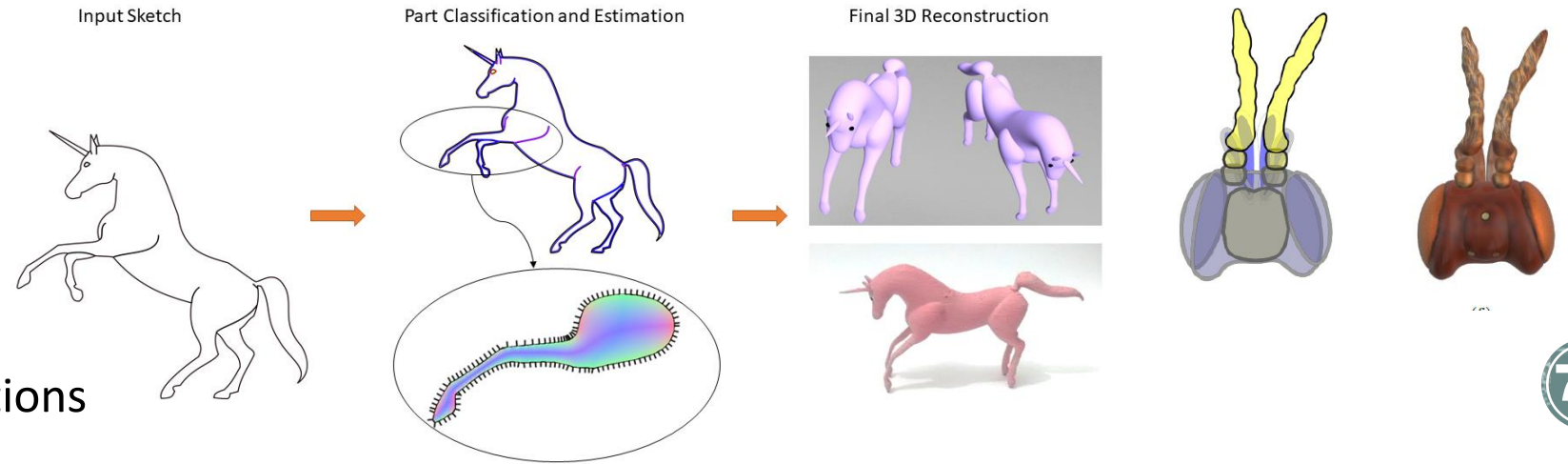
c)

d)

Thesis Roadmap

- Introduction
  - About this Thesis
  - Importance of Sketches
  - Sketch-based Systems
  - Objectives
- Related Work
- Overview
- Automatic Framework
- Interactive Framework
  - **Entomology Applications**
- Conclusions and Future Directions





Application and Analysis for Biological Systematic Illustrations

Most important structures for diagnosing dipteran species:

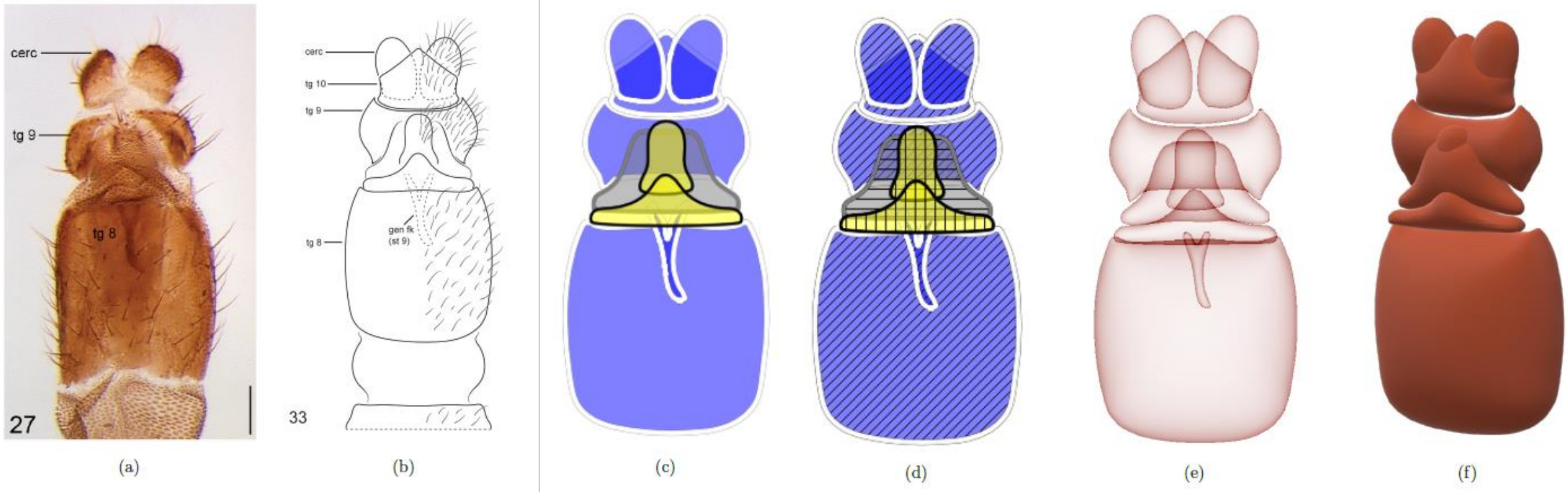
- Wing
- Head Capsule
- Terminalia

We focus our framework on such features.

Illustrator workflow:

- Careful drawing process
- Stereo and optical microscopes
- Camera lucida.

Application and Analysis for Biological Systematic Illustrations



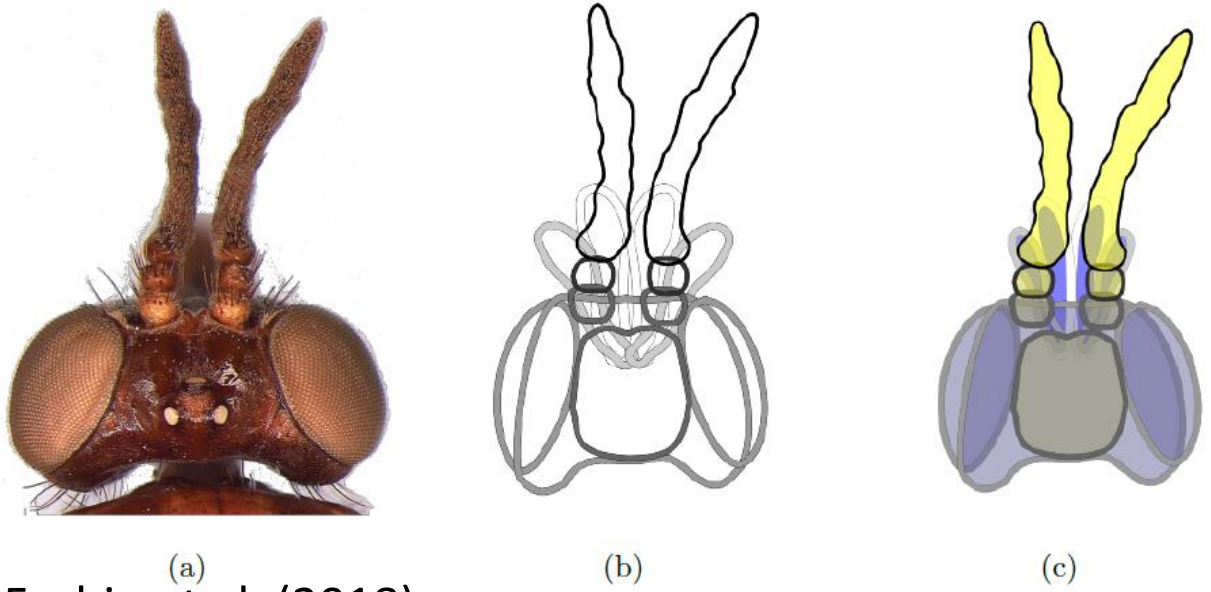
Fachin et al. (2018)

Application and Analysis for Biological Systematic Illustrations

The head contains 6 segments divided in pairs.

Surfaces reconstructed using Rotational Blending Surfaces

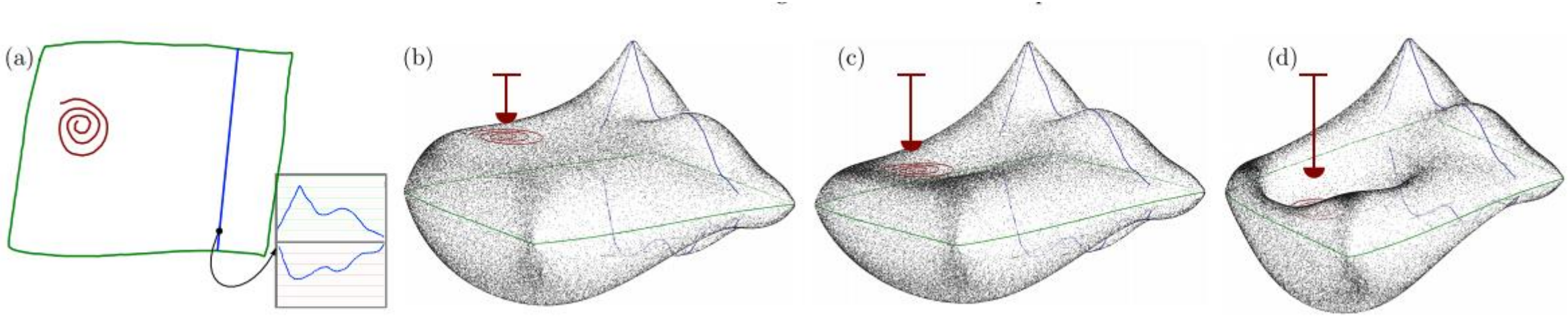
Divided in layers and different depths



Fachin et al. (2018)

Interactive Framework: Future Directions

- Mesh edition would improve 3D models
- Concave or convex surfaces, such as wings and shells
- Models better described with 2 or more views



Vital Brazil et al. (2010)

Interactive Framework: Future Directions

Inclusion of textures based on images and photographs.

Specially for scientific drawings.

Callieri et al. (2008)

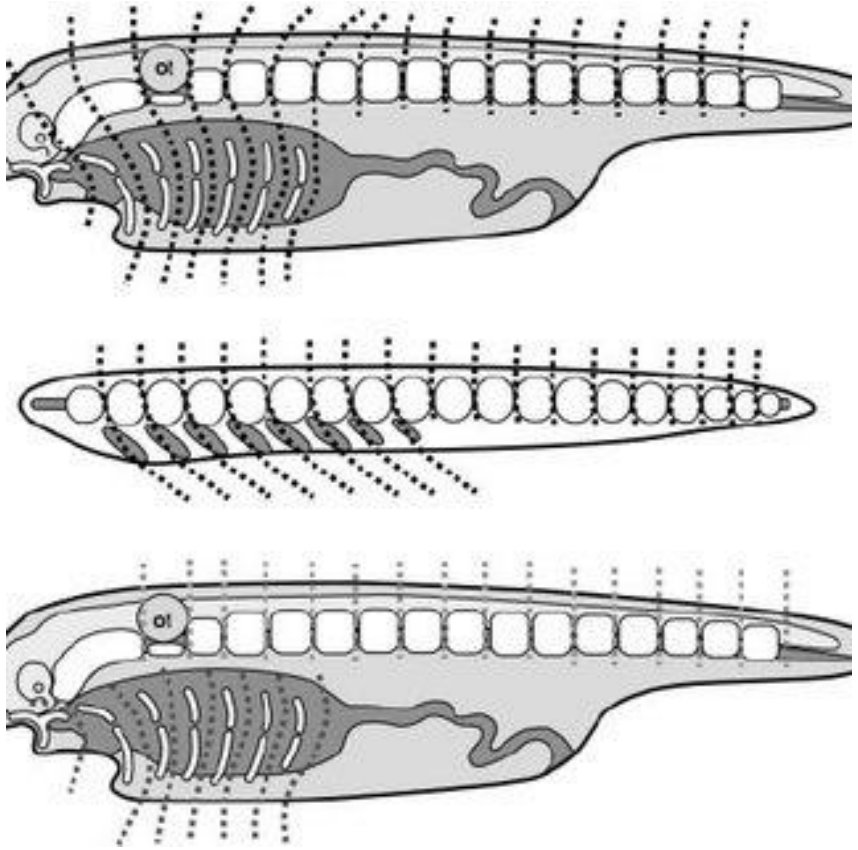
Interactive Framework: Future Directions

"Metameric Reconstruction"

Metameric segmentation:

- architectural body plan in some animals
- the similar body segments and organ systems are serially repeated

The similar body segments are called metameres or somites.



Kuratani, (2003)

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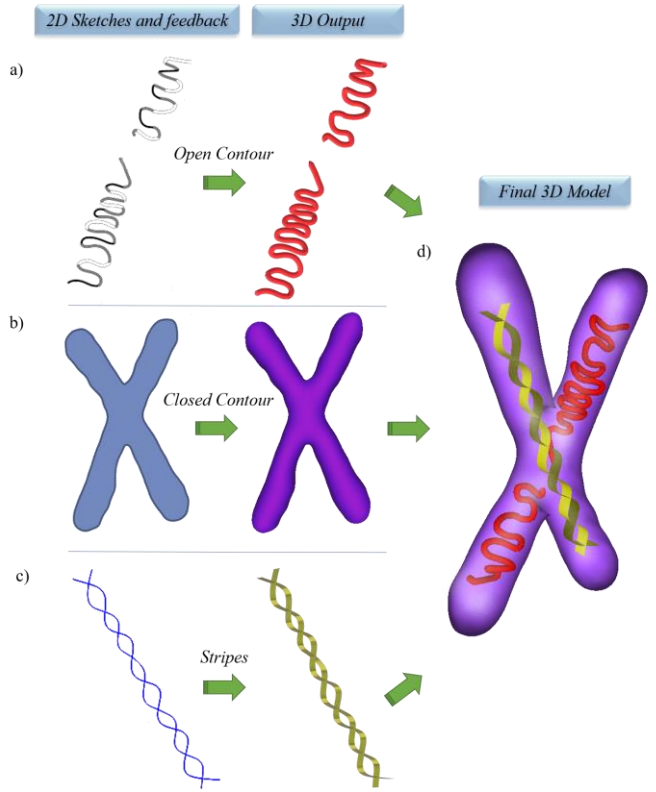
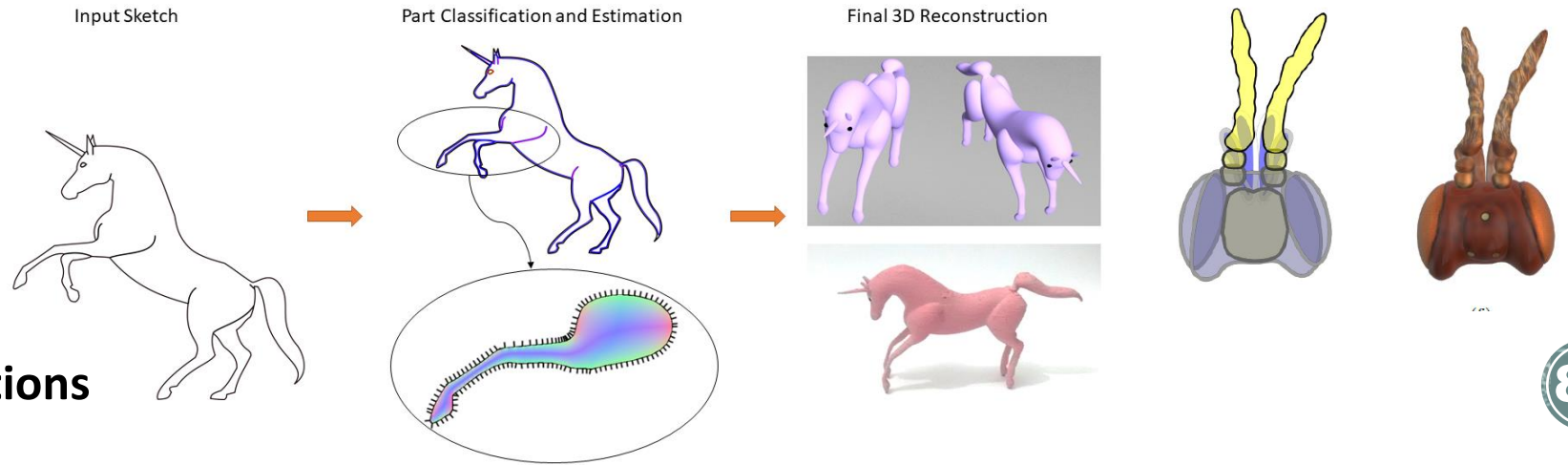
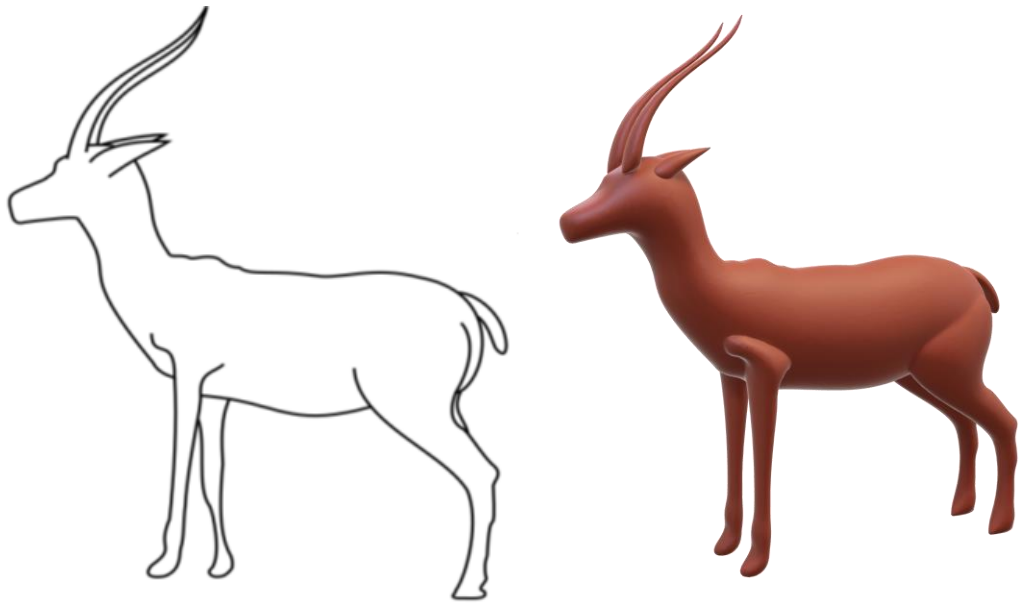




Conclusions and Future Directions

We presented an automatic method for 3D reconstruction from sketches (Chapter 4).

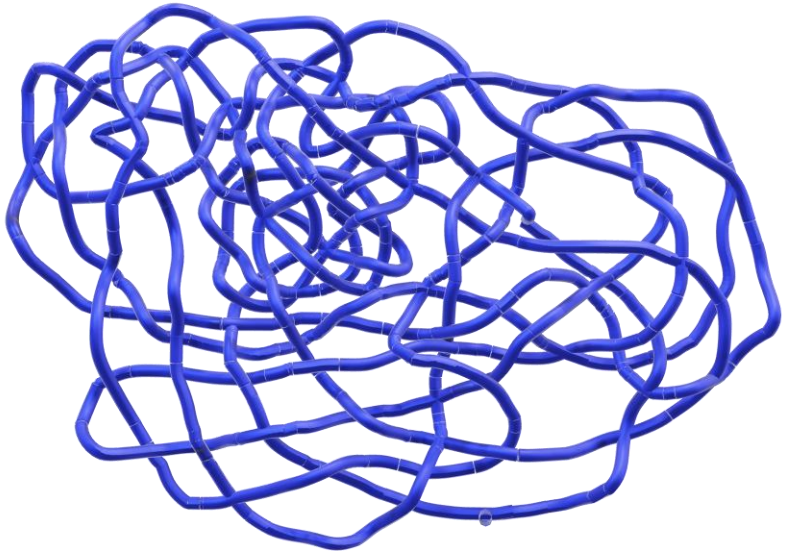
- First study that explores the problem of reconstruction from a single-view sketch with a skeleton-free technique
- Eliminates the use of skeletons to reconstruct the parts
- Estimation of depth and 3D models using a normal propagation method
- Addition to the reconstruction, parts not identified in previous work

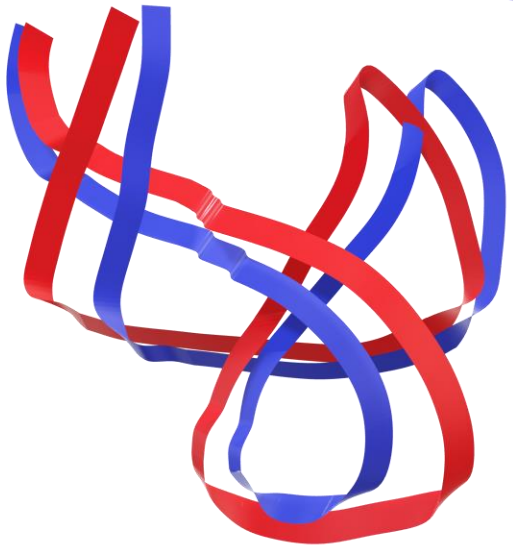


Conclusions and Future Directions

We presented an SBIM system tailored for single-view overlaying sketches (Chapter 5).

- Creation of models for different categories of contours:
    - Open contours for knots
    - Closed contours for 3D surfaces,
    - Modeling 3D stripes as bands with twists.





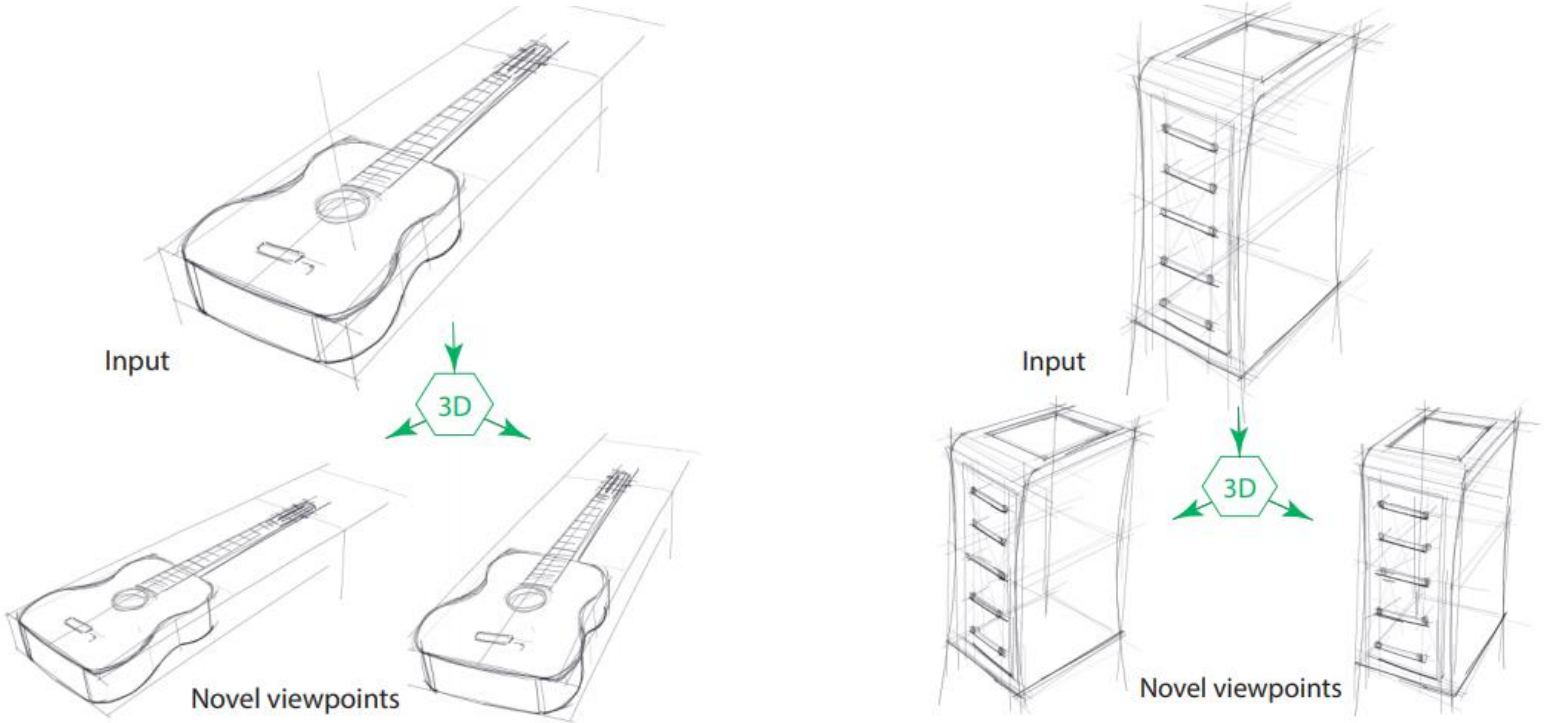
As an application

- Model entomological features of Dipteras
- Flies and mosquitoes group.

Conclusions and Future Directions

Develop frameworks that can address

- Connectivity problems using designer observations
- 3D intersection detection as recently proposed by Gryaditskaya et al. [45].

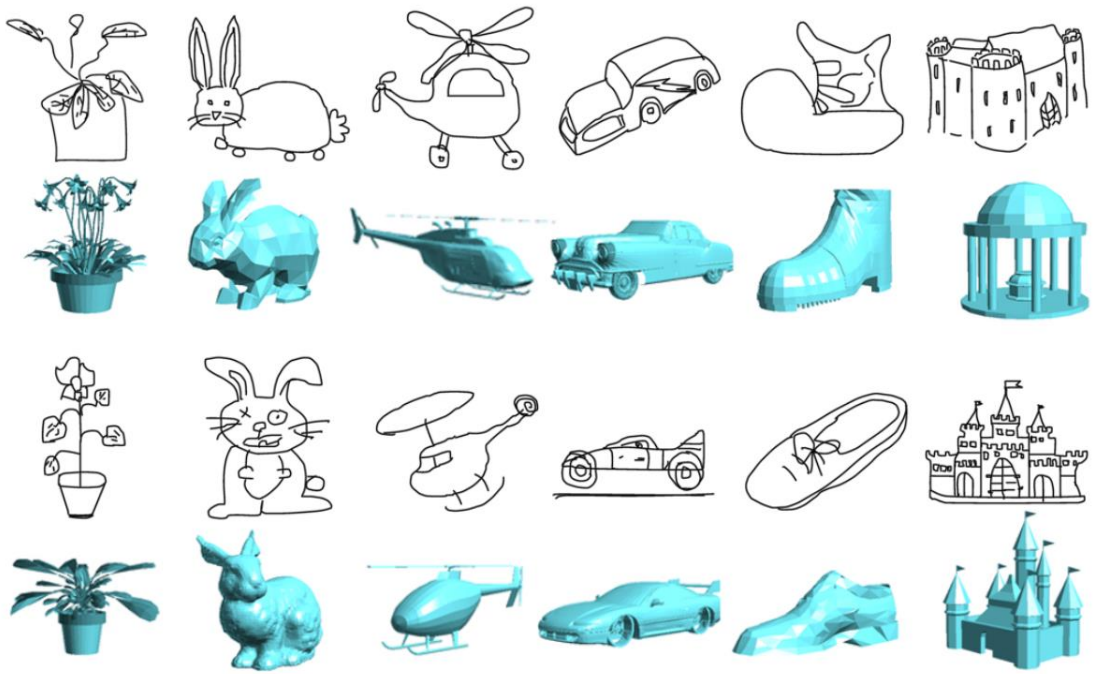


Gryaditskaya et al. (2020)

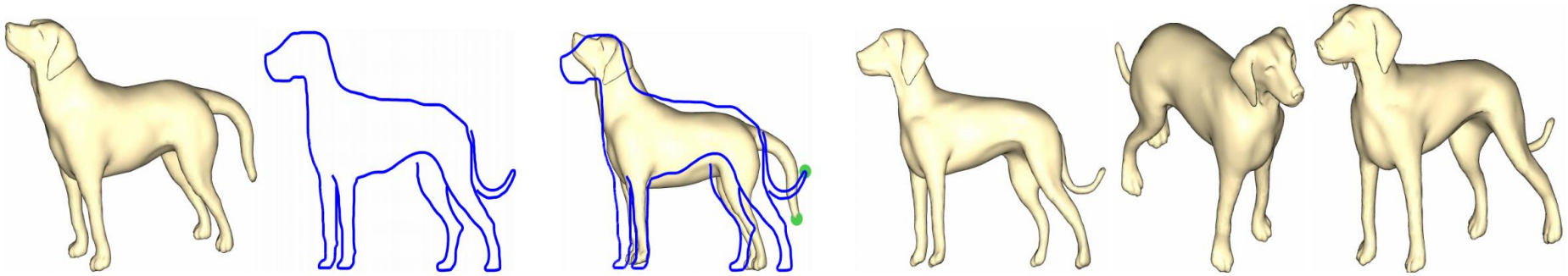
Conclusions and Future Directions

Creation of a web portal
- Species descriptions
- Drawings
- 3D models.

Develop deep and machine learning 3D model retrieval and reconstruction from datasets.

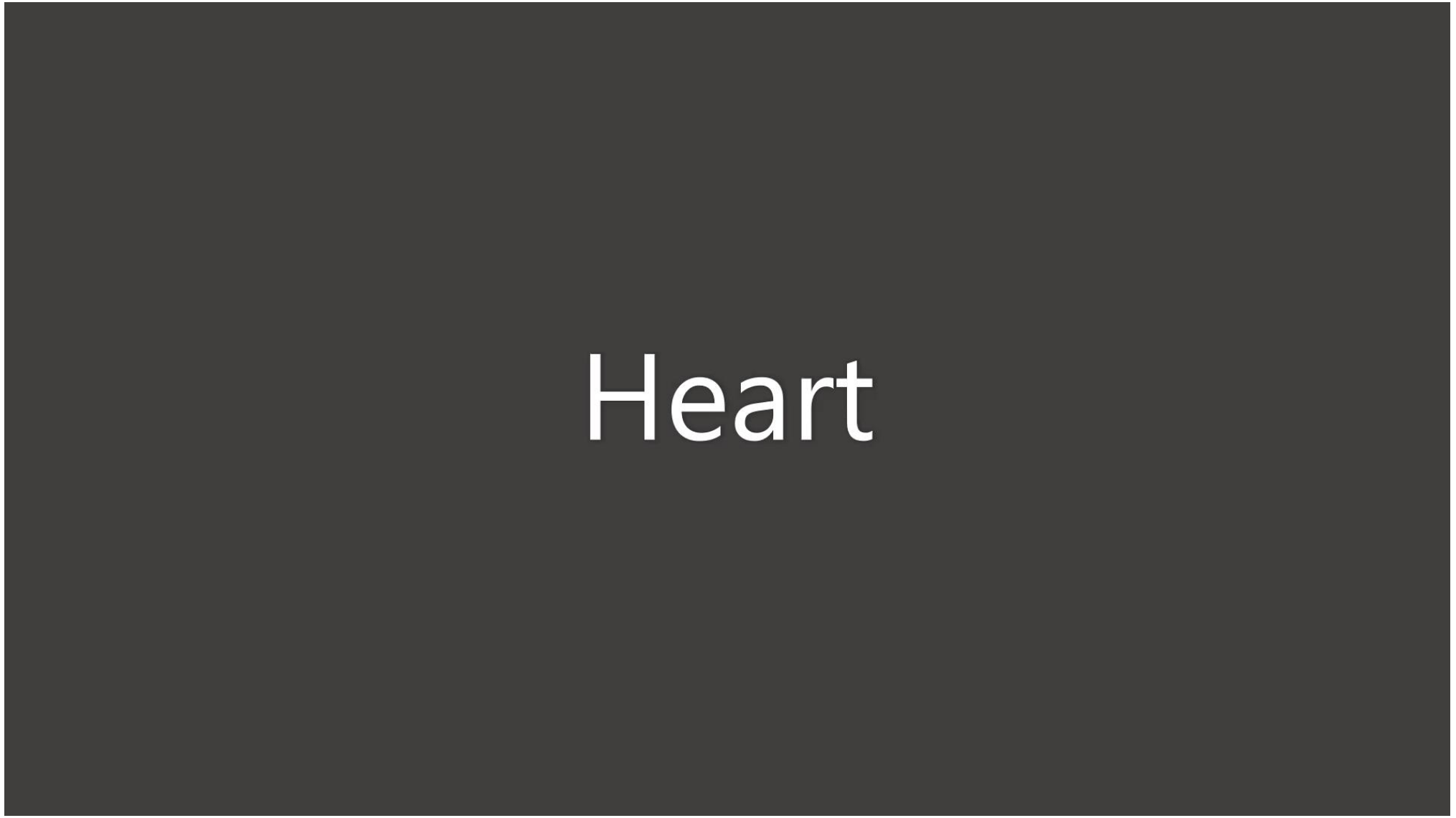


Wang et al. (2015)

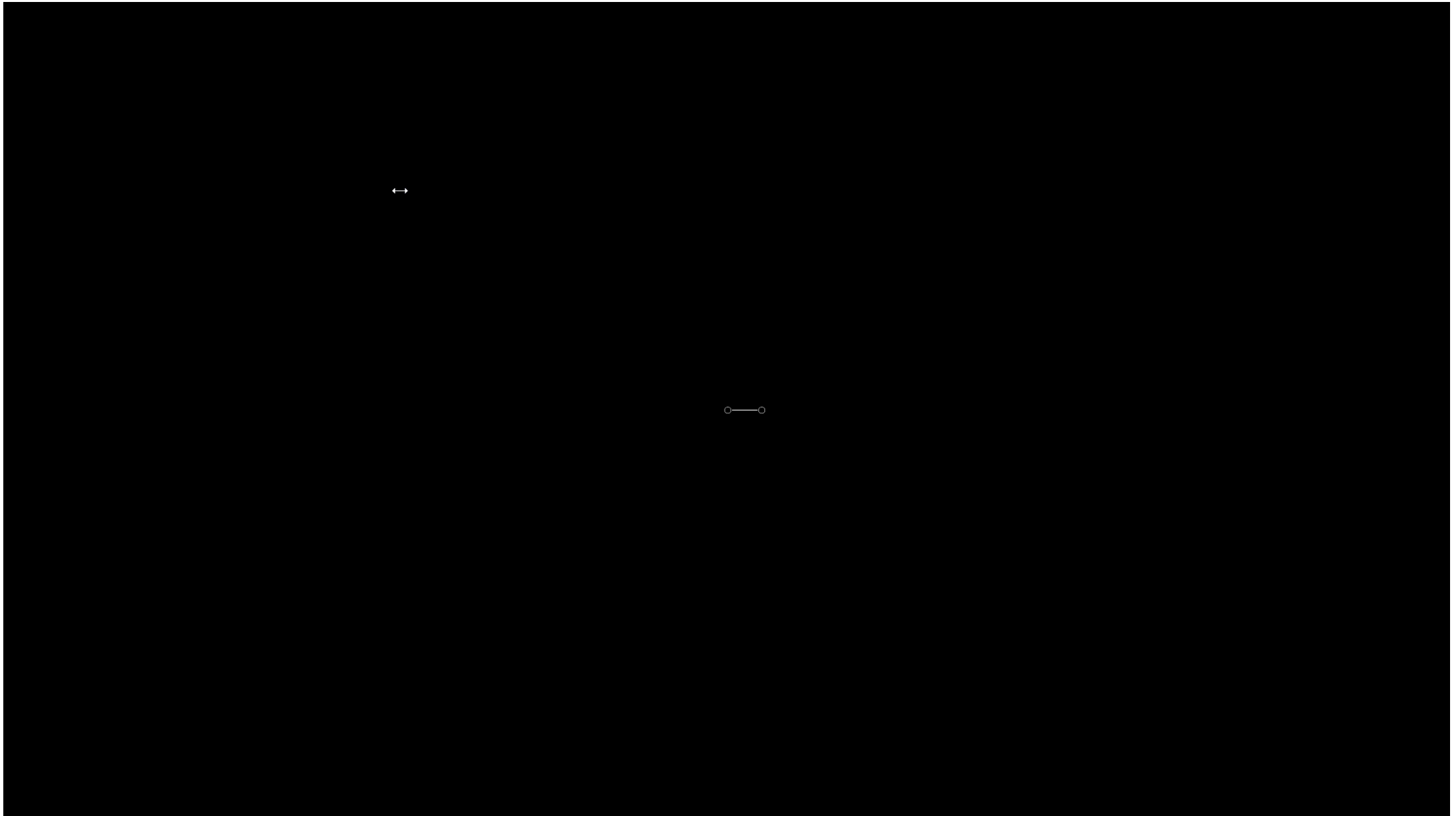


Kraevoy et al. (2009)

Automatic Framework: Results



Interactive Framework: Results



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Luke Olsen, Faramarz F Samavati, Mario Costa Sousa, and Joaquim A Jorge. Sketch-based modeling: A survey. Computers & Graphics, 33(1):85{103, 2009.

Chen Yang, Dana Sharon, and Michiel van de Panne. Sketch-based modeling of parameterized objects. In SIGGRAPH Sketches, page 89. Citeseer, 2005.

Vladislav Kraevoy, Alla Sheffer, and Michiel van de Panne. Modeling from contour drawings. In Proceedings of the 6th Eurographics Symposium on Sketch-Based interfaces and Modeling, pages 37{44. ACM, 2009.

Alec Rivers, Fredo Durand, and Takeo Igarashi. 3d modeling with silhouettes. ACM Trans. Graph., 29(4):109:1{109:8, July 2010. ISSN 0730-0301. doi: 10.1145/1778765. 1778846. URL http://doi.acm.org/10.1145/1778765.1778846.

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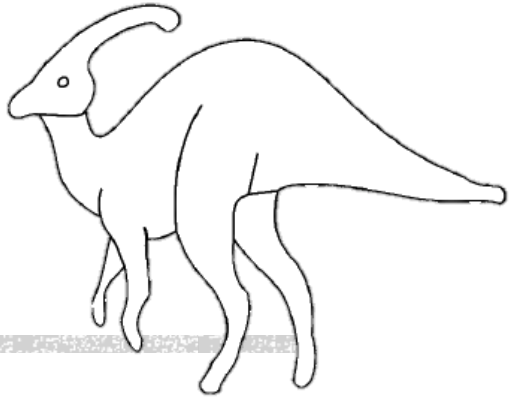
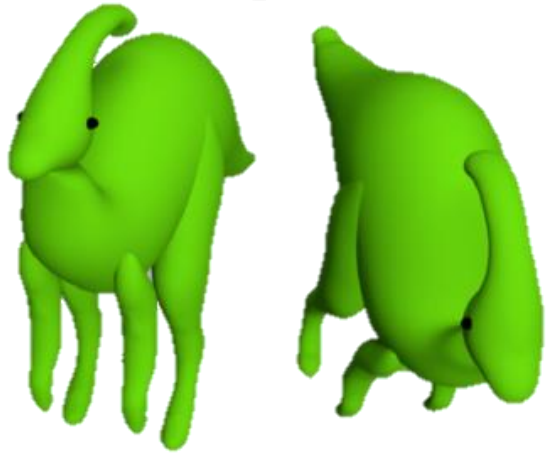
Sketch-based modeling from Single-view drawings and Applications



Saulo Ramos de Carvalho Pereira srdcp@hotmail.com

Mario Costa Sousa

João Paulo Gois



UFABC UNIVERSITY OF CALGARY CAPES

Why HRBF?

- In the following, we enumerate the main properties and contributions of HRBF implicits.

- *Global implicit interpolant surface of Hermite data:* HRBF implicits aim at computing a global implicit function whose zero-level interpolates given points and their derivatives, in our case, the normal vectors.
- *Offsets-free:* Differently from previous RBF interpolants, HRBF implicits do not require any heuristics for creating off-surface points improving robustness.
- *Capability of handling irregularly-spaced data:* Similarly to previous RBF-based methods, the HRBF implicits method is also able to compute reasonable interpolations even in the presence of irregular data distributions.
- *Flexibility for true Hermitian data sets:* Although we consider in the present formulation “Hermitian data” as a set of scattered points and their associated normal vectors, the HRBF implicits method is more general since it allows constraining arbitrary gradient vectors for the implicit function on the sample points.
- *Capability to handle close sheets:* Our results show that HRBF implicits allow for computing surfaces with close sheets [2], [7], and indicate that our Hermite-interpolatory method is superior to previous solutions in this situation.
- *Simple implementation:* Our formulation and subsequent treatment build upon theoretical results from scattered data approximation theory [6] and concepts from functional analysis [10], yet it leads to a simple matrix-based algorithm that is a direct translation of the mathematical results.
- This allows a simple computational implementation general enough to be independent of the ambient space dimension. Moreover, the theoretical framework supporting HRBF implicits indicates directions to build variants of the basic method which may allow further flexibility

Why HRBF?

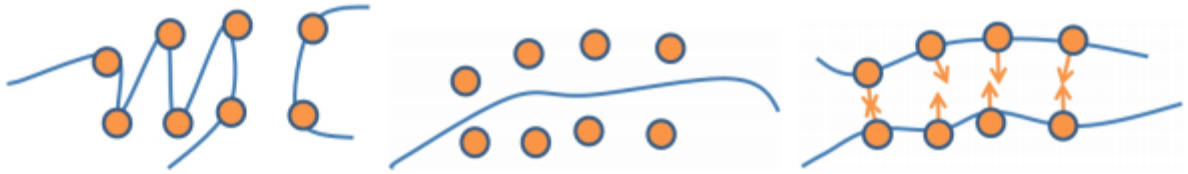
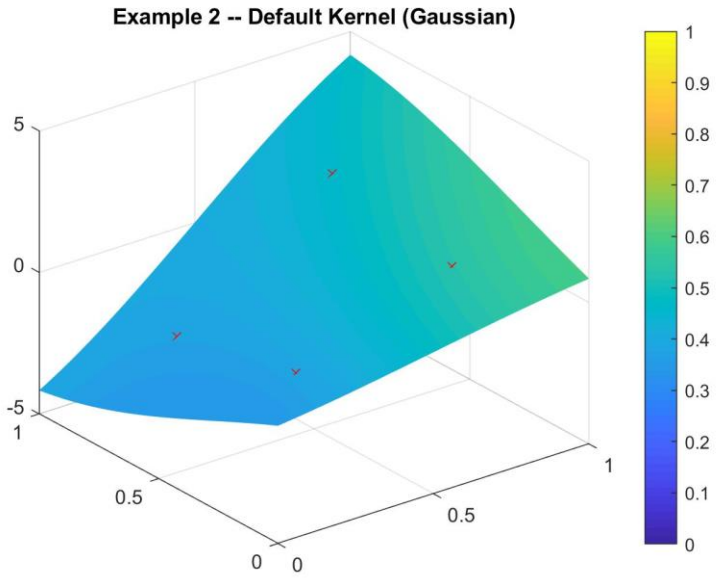
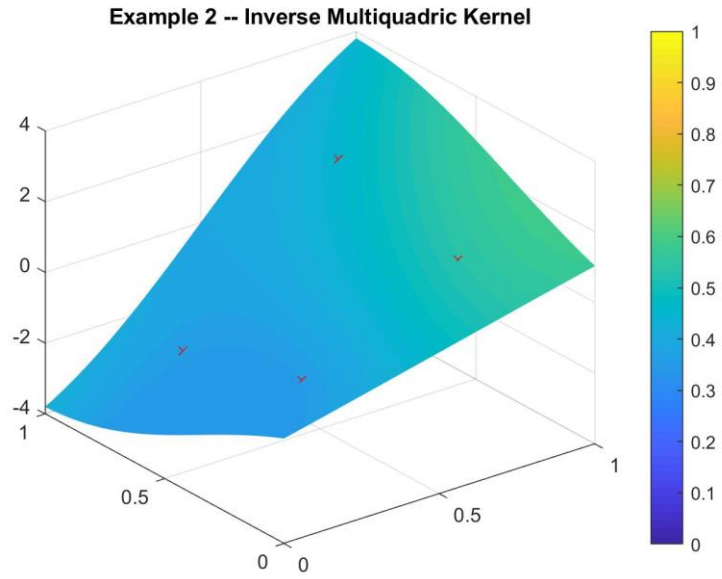
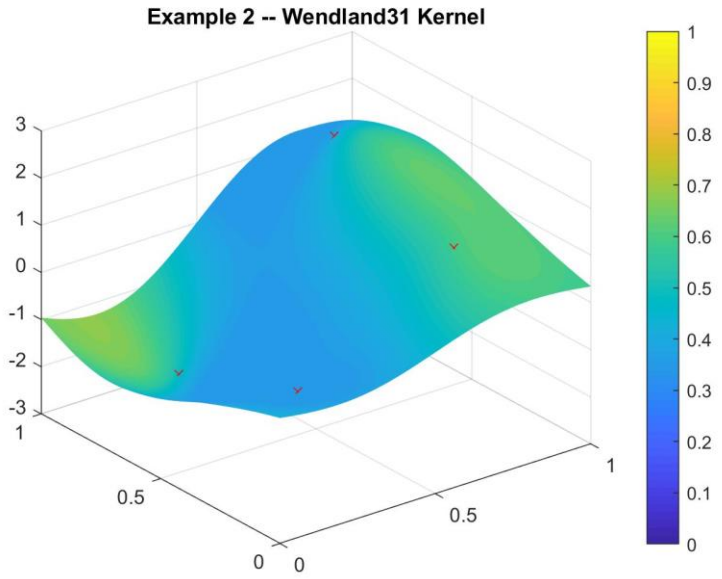


Figure 2. The issue of *close sheets* (see [2], [7]): when two parts of the surface are very close, many interpolation/approximation techniques behave poorly. Case (a) is an example of undesired interpolation, whereas case (b) is an example of undesired approximation. HRBF implicits, since it interpolates both points and normals, produces results similar to (c).

Why HRBF?


Example 2 -- Default Kernel (Gaussian)
5
0
-5
1
0.5
0
0
0.5
1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

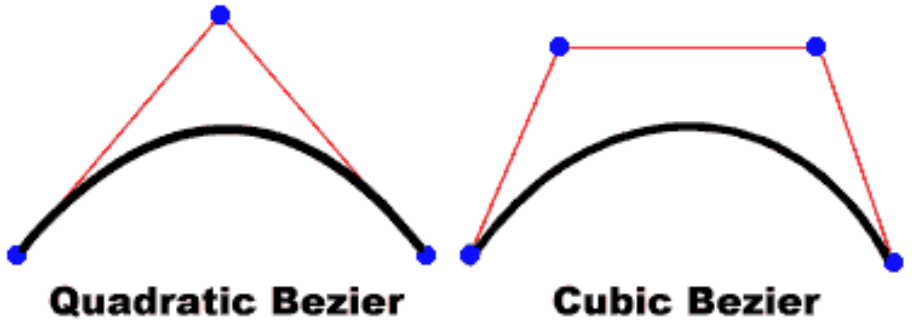

Example 2 -- Inverse Multiquadric Kernel
4
2
0
-2
-4
1
0.5
0
0
0.5
1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


Example 2 -- Wendland31 Kernel
3
2
1
0
-1
-2
-3
1
0.5
0
0
0.5
1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Why not Gestalt Principles?

- Mainly because of inference
- In our work, we focused in translate the user actual drawing differently from intention
- Intention vs Actual Drawing
- What you sketch is what you get

Bezier Curves



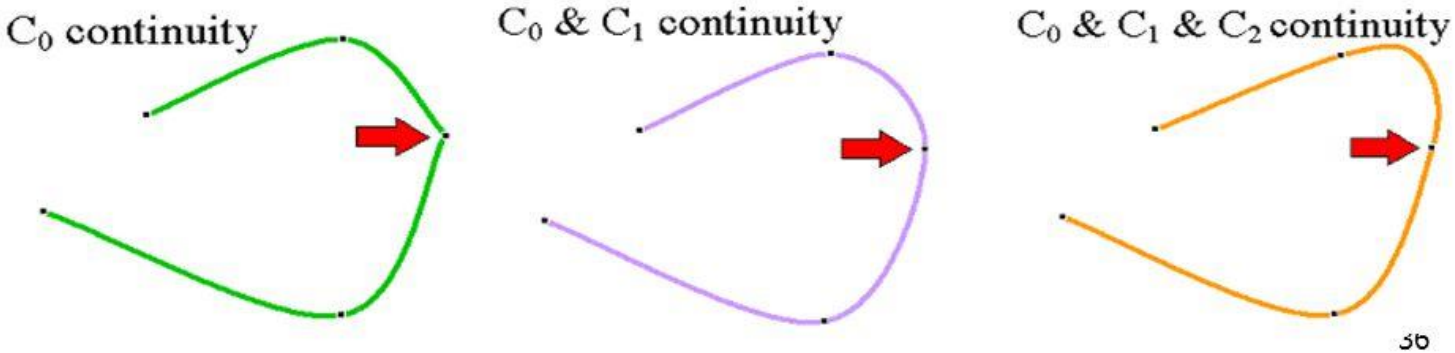
$$x(t) = (1-t)^3 \cdot x_0 + (1-t)^2 \cdot 3t \cdot x_1 + (1-t) \cdot 3t^2 \cdot x_2 + t^3 x_3$$

$$y(t) = (1-t)^3 \cdot y_0 + (1-t)^2 \cdot 3t \cdot y_1 + (1-t) \cdot 3t^2 \cdot y_2 + t^3 y_3$$

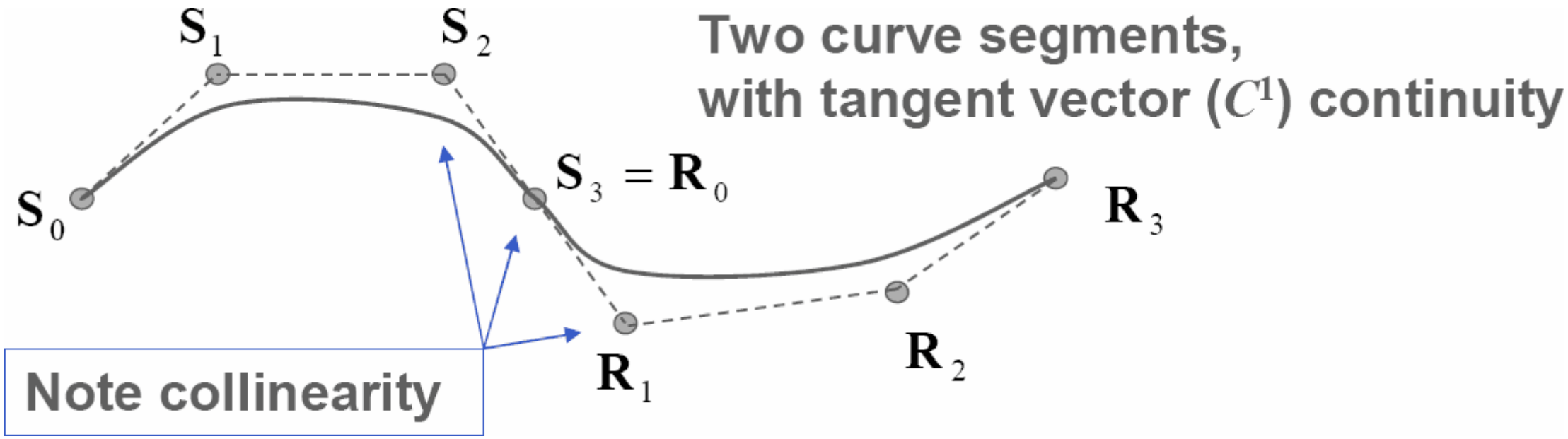
C^1 Continuity

Continuity

- when two curves joined, typically want some degree of continuity across knot boundary
  - C0, “C-zero”, point-wise continuous, curves share same point where they join
  - C1, “C-one”, continuous derivatives
  - C2, “C-two”, continuous second derivatives

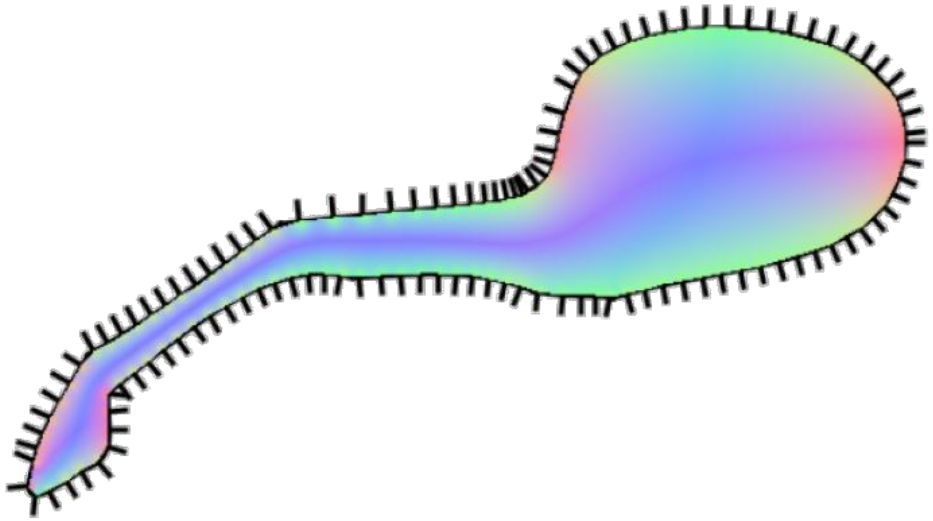


C^1 Continuity



C^1 Continuity

Generating 3D Hermitian data



$$n_x(p) = \frac{1}{\omega(p)} \int_C \frac{n_{\{x\}}(s)}{|p - C(s)|^2} ds,$$

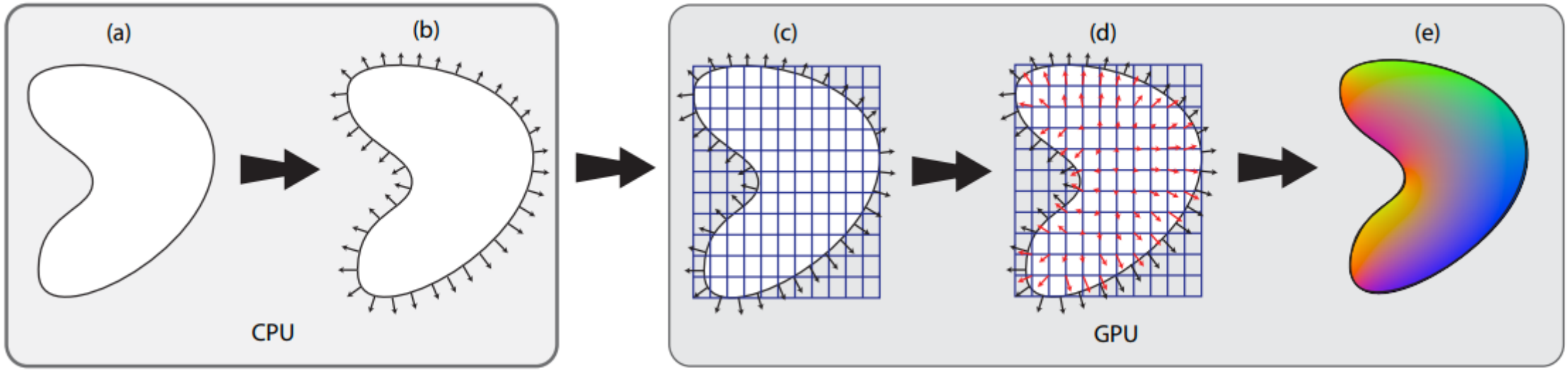
$$n_y(p) = \frac{1}{\omega(p)} \int_C \frac{n_{\{y\}}(s)}{|p - C(s)|^2} ds,$$

$$\omega(p) = \int_C \frac{ds}{|p - C(s)|^2},$$

$$n_z(p) = \sqrt{1 - n_x(p)^2 - n_y(p)^2}.$$

Nascimento et al. (2011)

Generating 3D Hermitian data



$$n_{\{x,y\}} = \frac{\sum_{i=1}^{N} \frac{\mu_{i_{\{x,y\}}}}{\|p - p_i\|^2}}{\omega} \qquad (1)$$

where

$$\omega = \sum_{i=1}^{N} \frac{1}{\|p - p_i\|^2}. \qquad (2)$$

The normalization of the normal vector in p is ensured by imposing

$$n_z = \sqrt{1 - n_x^2 - n_y^2}. \qquad (3)$$

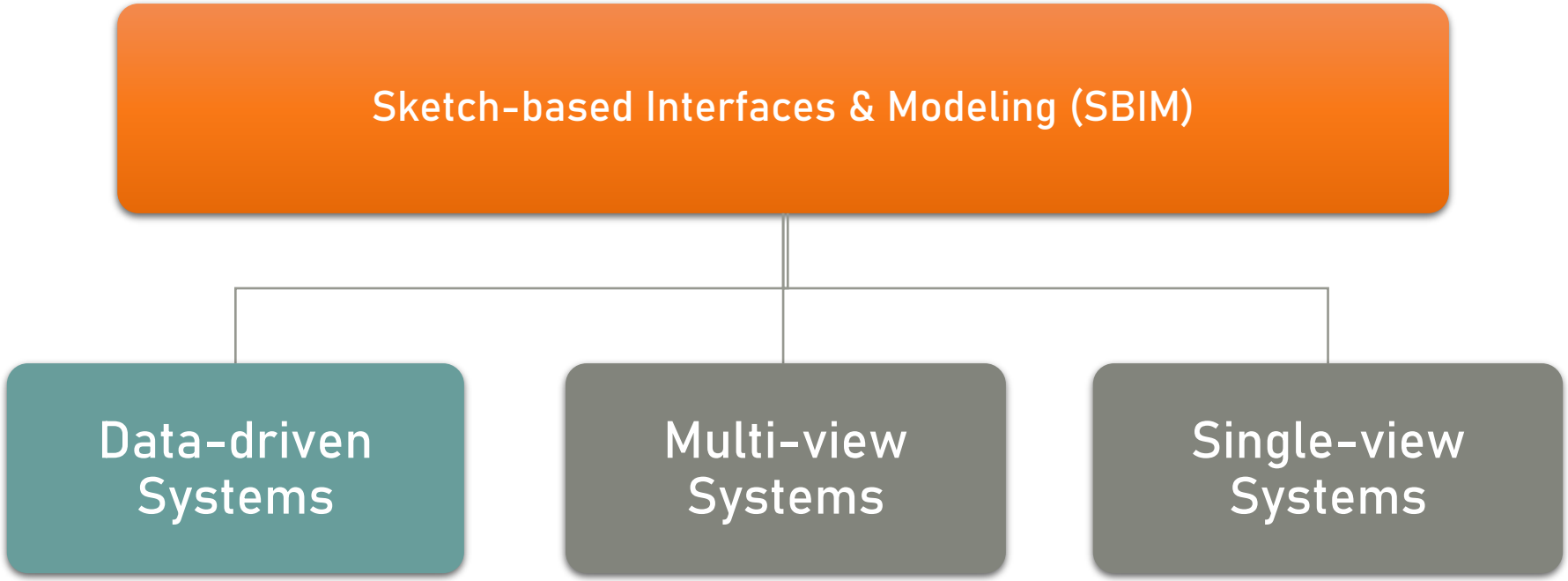
Gois et al. (2015)

Algorithm Complexity

Normal Estimation on grid: $O(n^2)$
HRBF: $O(n^4)$

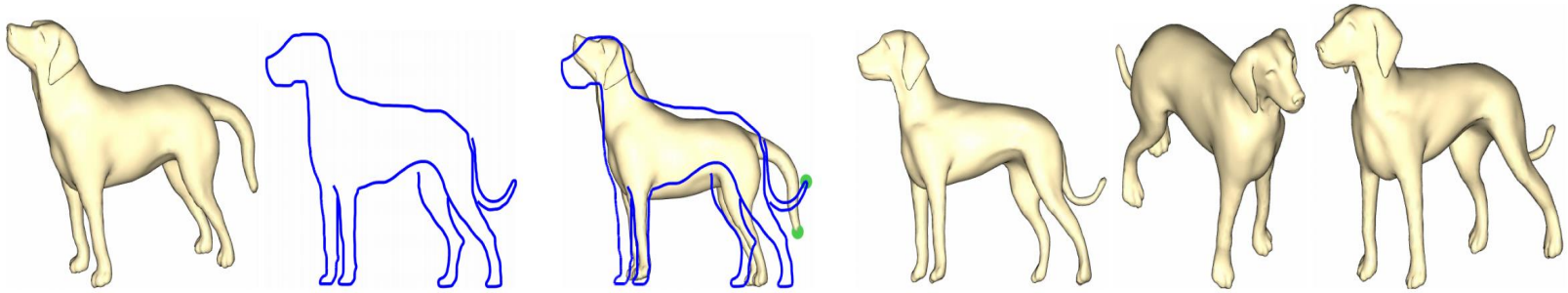
Rotational Blending Surface: $O(n.m) \Rightarrow O(n)$

Related Work: Overview

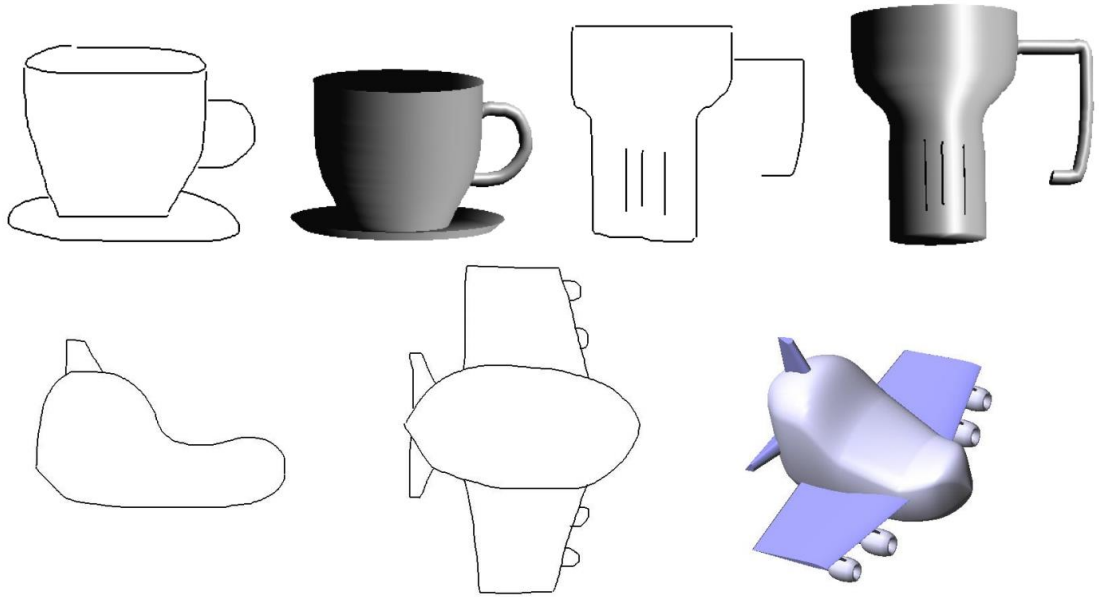


Related Work: Data-driven Systems

- Based on search engines
- Input
  - Image or 2D sketches
  - Annotations
- Results
  - 3D Models
  - Deformed 3D Models
- Lack of databases

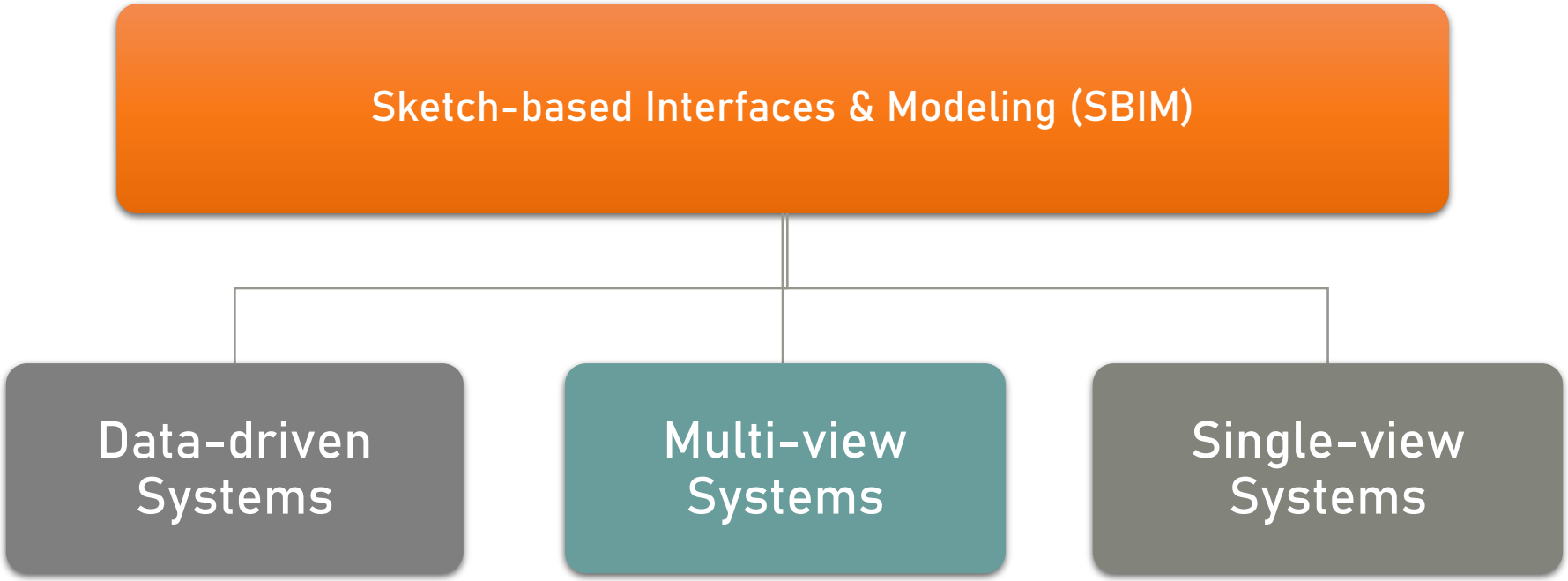


Kraevoy et al. (2009)



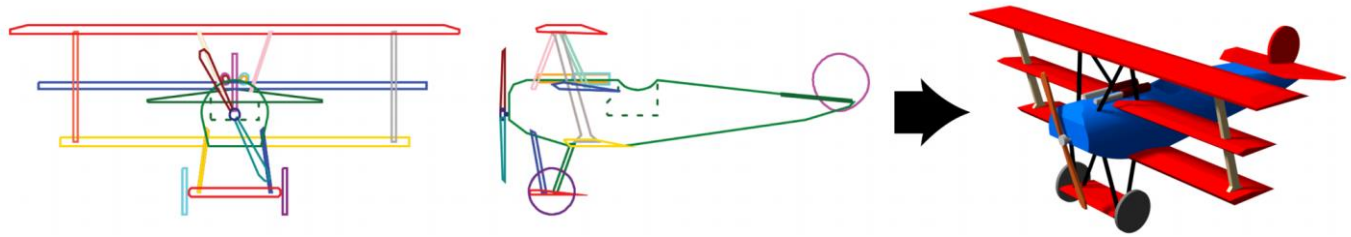
Yang et al. (2005)

Related Work: Overview

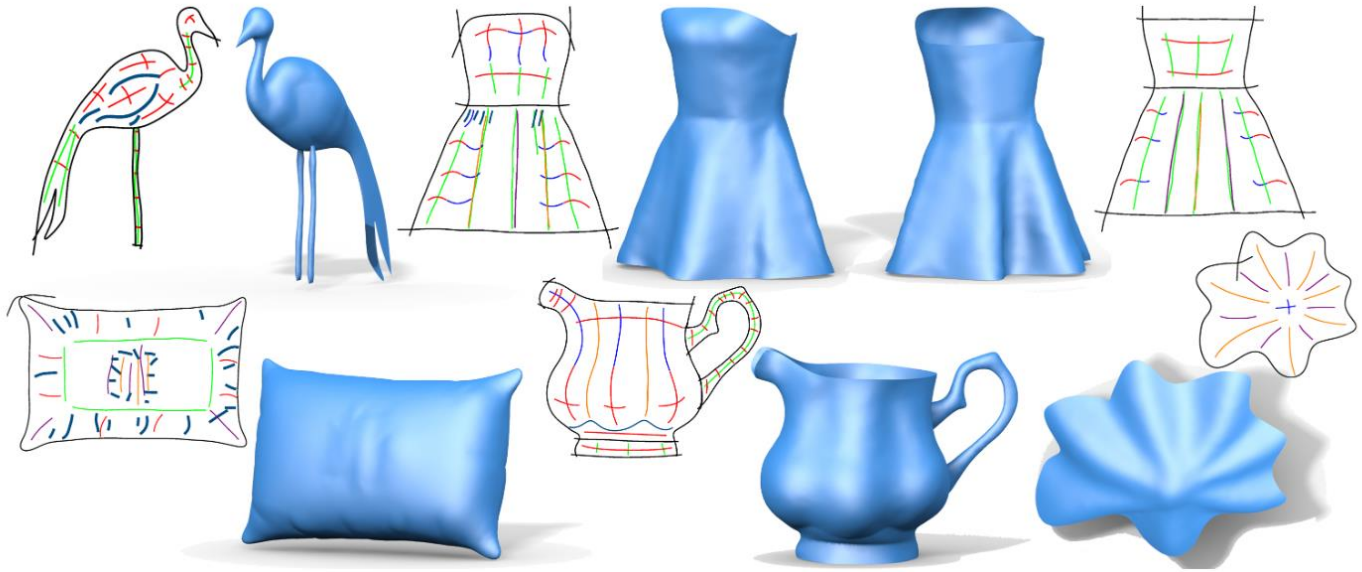


Related Work: Multi-view Systems

- Uses 2 or more views
- Input
  - Ortographic Views
  - Avatars and Skeletons
  - Interactively drawn
- Combine multiple view
- Sequentially create and refine parts



Rivers et al. (2010)



Li et al. (2017)