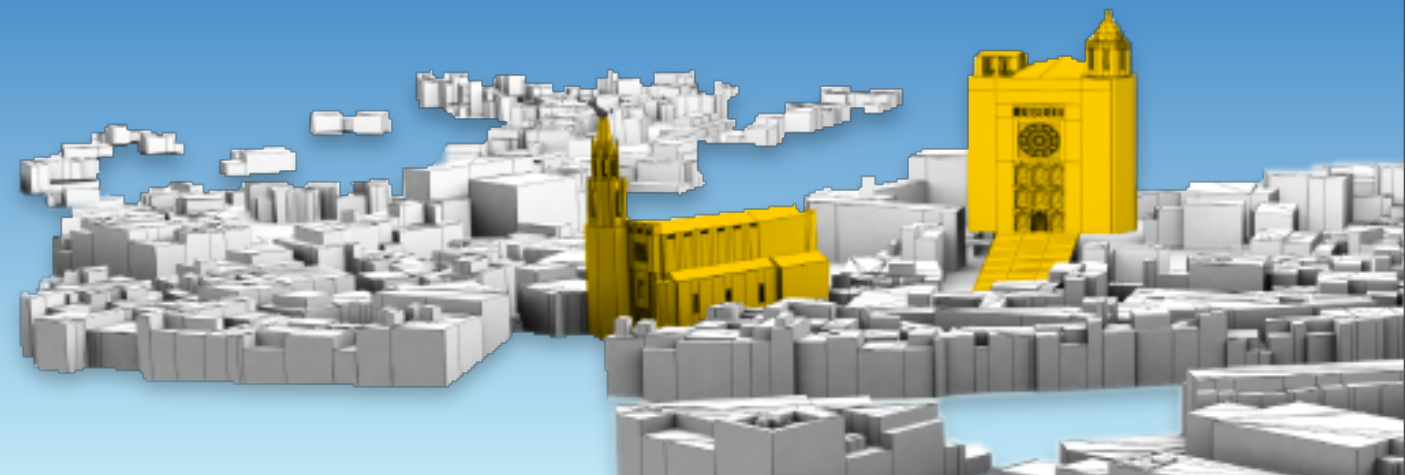




# Eurographics 2013

May 6-10, Girona (Spain)



*State-of-the-art Report*  
*on*  
***Structure-Aware Shape Processing***

*Niloy J. Mitra*

*Michael Wand*

*Hao Zhang*

*Daniel Cohen-Or*

*Martin Bokeloh*



# Structure

# Structure

*a **complex system** considered  
from the point of view of the **whole**  
rather than of any single part*

# Structure

*a **complex system** considered  
from the point of view of the **whole**  
rather than of any single part*

*anything **composed of parts**  
**arranged** together in some way  
an organization*



# Models in Science

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## Models in Science

*First published Mon Feb 27, 2006; substantive revision Mon Jun 25, 2012*

Models are of central importance in many scientific contexts. The centrality of models such as the billiard ball model of a gas, the Bohr model of the atom, the MIT bag model of the nucleon, the Gaussian-chain model of a polymer, the Lorenz model of the atmosphere, the Lotka-Volterra model of predator-prey interaction, the double helix model of DNA, agent-based and evolutionary models in the social sciences, and general equilibrium models of markets in their respective domains are cases in point. Scientists spend a great deal of time building, testing, comparing and revising models, and much journal space is dedicated to introducing, applying and interpreting these valuable tools. In short, models are one of the principal instruments of modern science.

Philosophers are acknowledging the importance of models with increasing attention and are probing the assorted roles that models play in scientific practice. The result has been an incredible proliferation of model-types in the philosophical literature. Probing models, phenomenological models, computational models, developmental models, explanatory models, impoverished models, testing models, idealized models, theoretical models, scale models, heuristic models, caricature models, didactic models, fantasy models, toy models, imaginary models, mathematical models, substitute models, iconic models, formal models, analogue models and instrumental models are but some of the notions that are used to categorize models. While at first glance this abundance is overwhelming, it can quickly be brought under control by recognizing that these notions pertain to different problems that arise in connection with models. For example, models raise questions in semantics (what is the representational function that models perform?), ontology (what kind of things are models?), epistemology (how do we learn with models?),

# Overview

- Introduction
- Model of structure
- Analysis
- Applications
- Conclusion and Future Challenges

# Overview

- ***Introduction***
- Model of structure
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# On Growth and Form

744 THE THEORY OF TRANSFORMATIONS [CH.

in which we may inscribe the outline of the lobster becomes a shortened triangle in the case of the crab. In a little more detail we may compare the outline of the carapace in various crabs one with another: and the comparison will be found easy and significant, even, in many cases, down to minute details, such as the

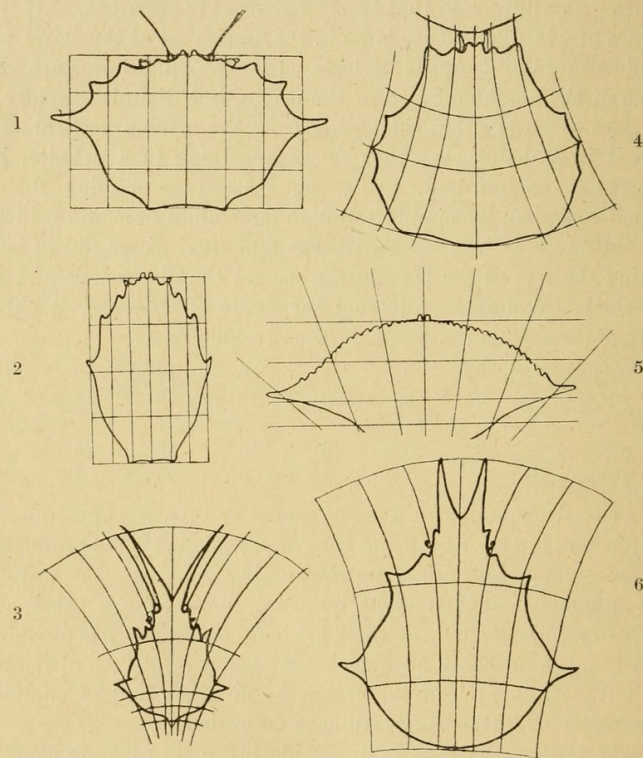


Fig. 369. Carapaces of various crabs. 1, *Geryon*; 2, *Corystes*; 3, *Scyramathia*; 4, *Paralomis*; 5, *Lupa*; 6, *Chorinus*.

number and situation of the marginal spines, though these are in other cases subject to independent variability.

If we choose, to begin with, such a crab as *Geryon* (Fig. 369, 1), and inscribe it in our equidistant rectangular co-ordinates, we shall see that we pass easily to forms more elongated in a transverse

For it is not a bundle of parts but an organization of parts, of parts in their ***relative arrangement***, . . . the coordinated parts, now as related and fitted *to the end or function* of the whole, and now as related to or resulting ***from the physical causes*** inherent in the entire system of forces to which the whole has been exposed.

Chapter XVI [Thompson 1892]

# Structure in Shapes



# Structure in Shapes



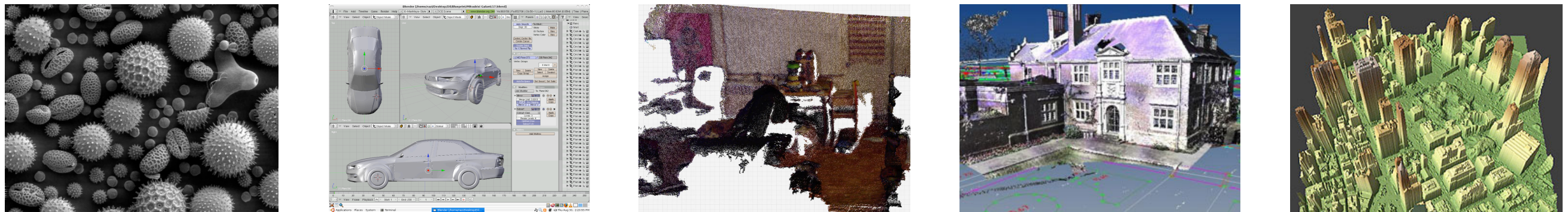
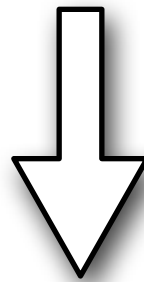
structures in nature



# Structure in Shapes



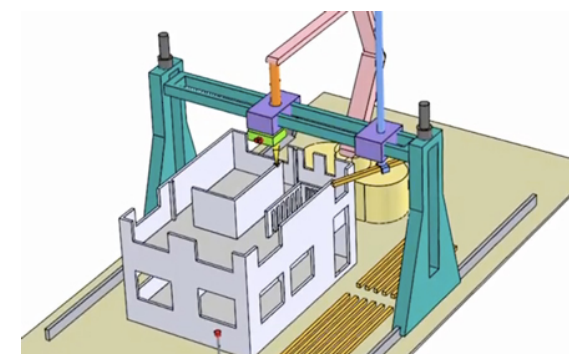
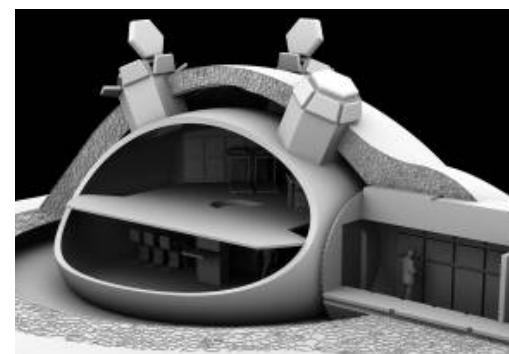
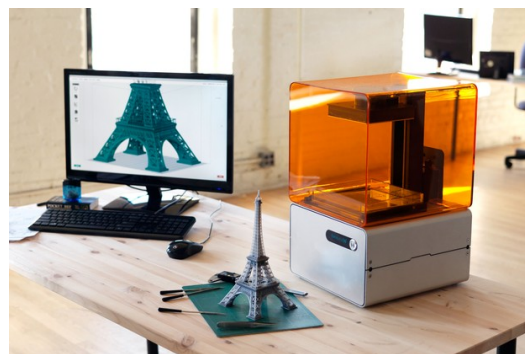
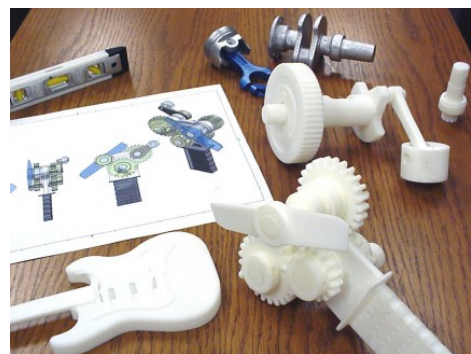
structures in nature



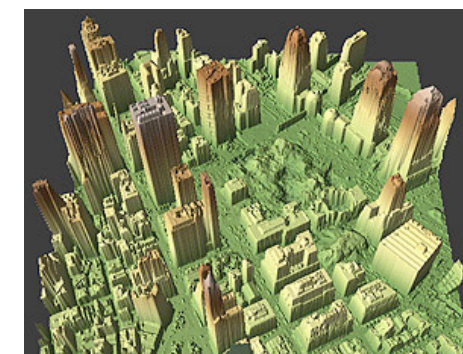
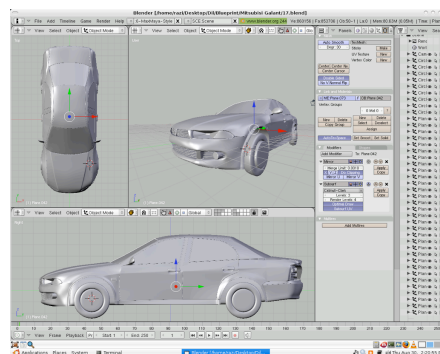
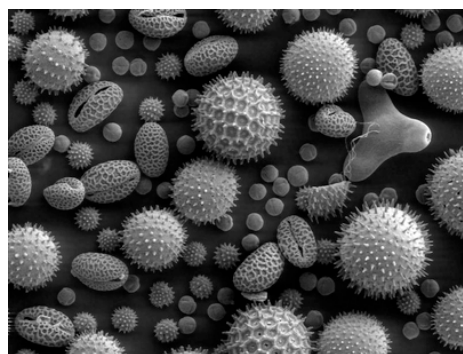
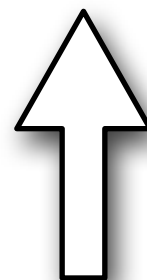
‘structures’ as captured



# Structure in Shapes



back to the world

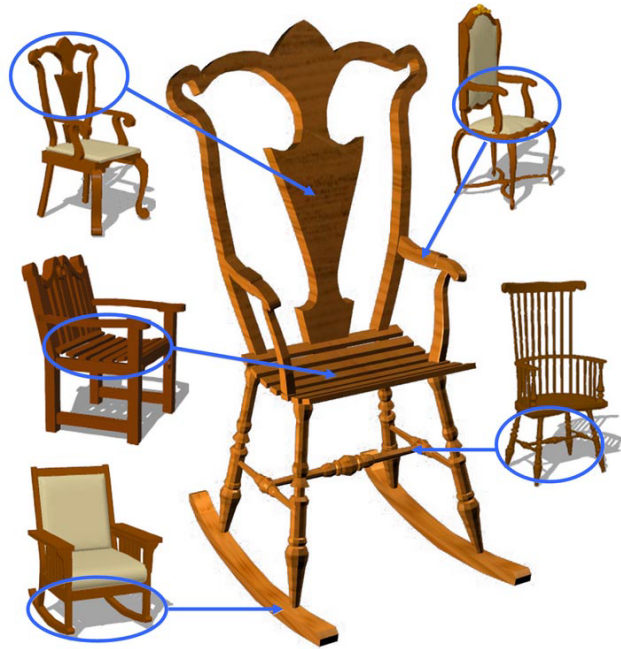


‘structures’ as captured



# Motivation

# Motivation

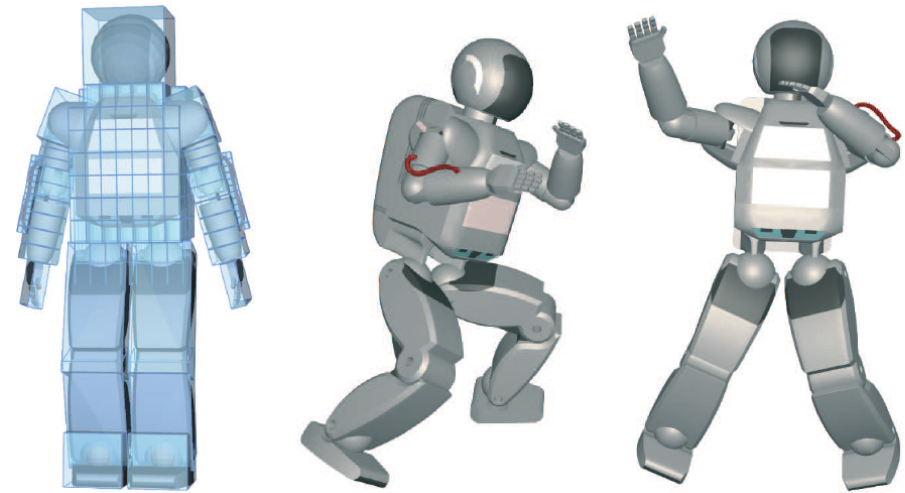


[Funkhouser et al. 04]

# Motivation



[Funkhouser et al. 04]

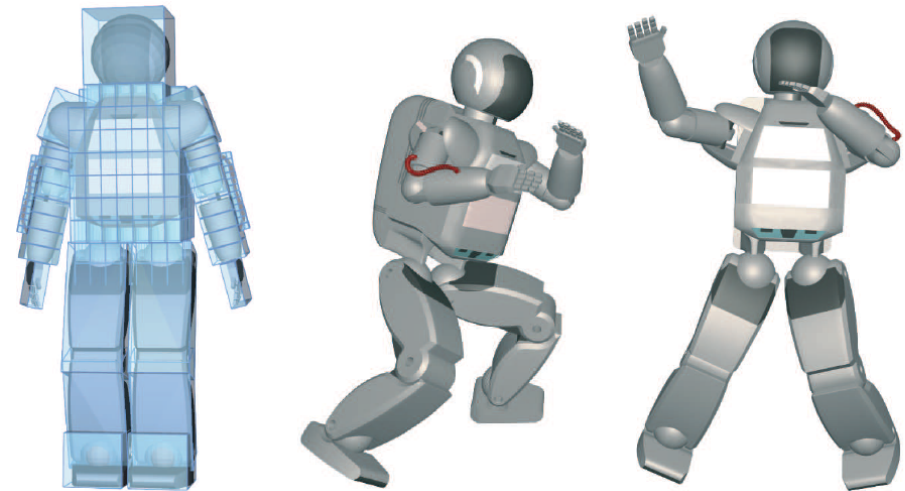


[Xu et al. 09]

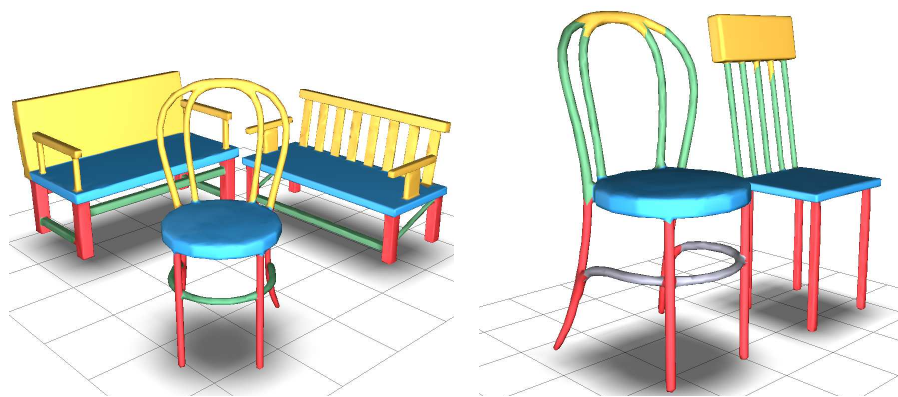
# Motivation



[Funkhouser et al. 04]

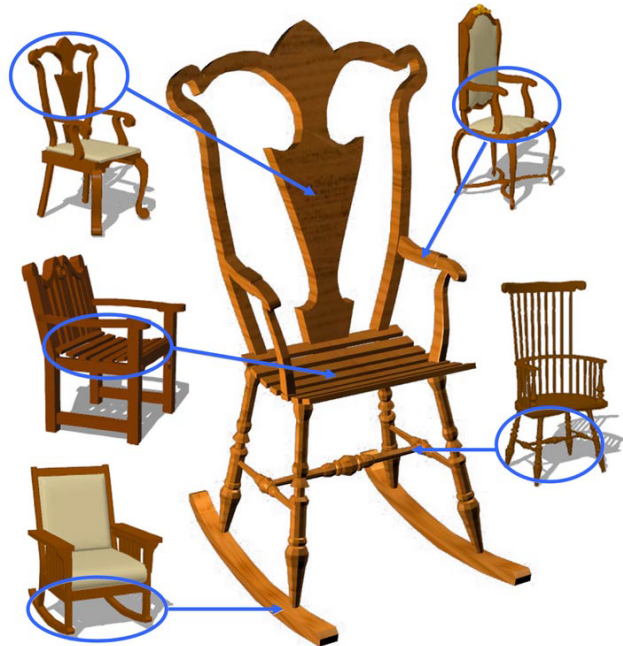


[Xu et al. 09]

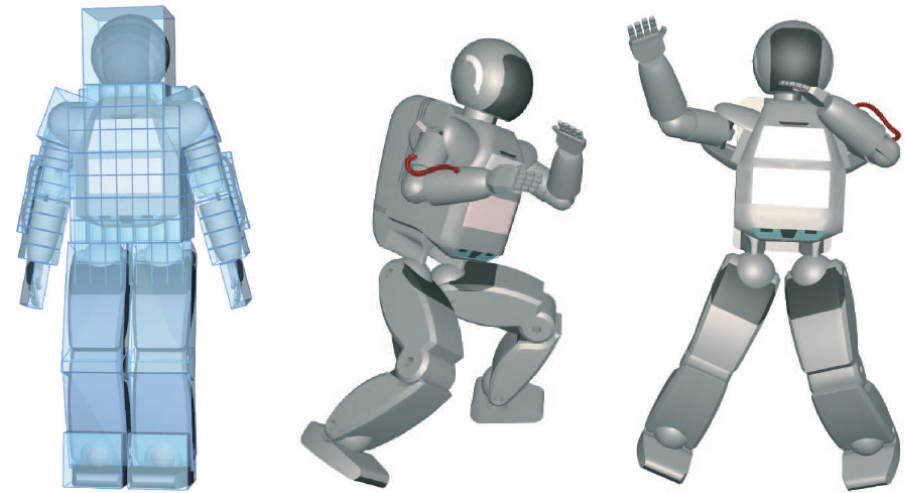


[Laga et al. 13]

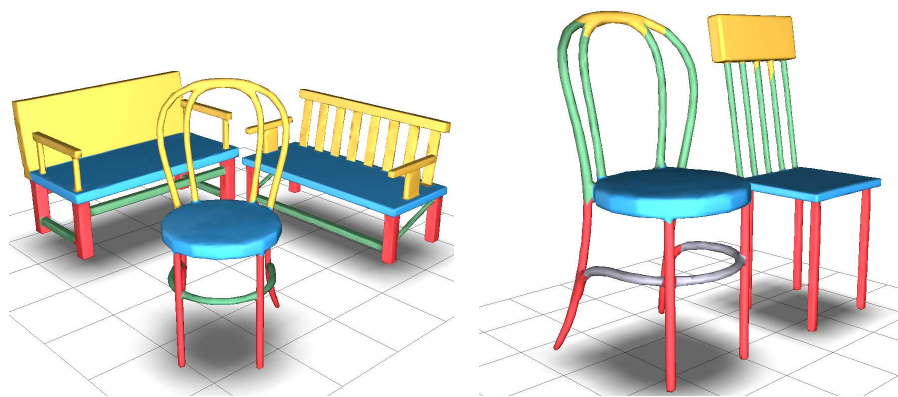
# Motivation



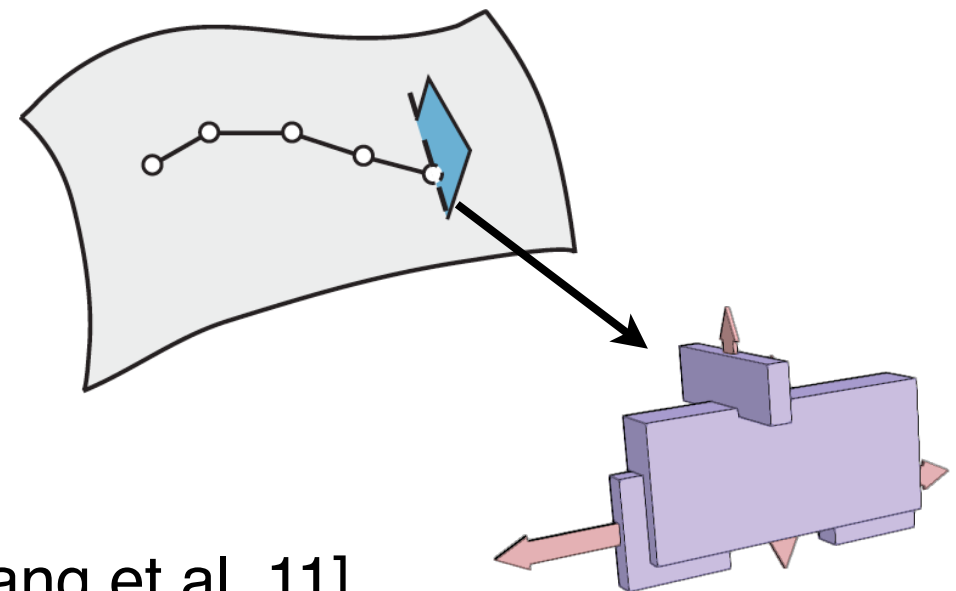
[Funkhouser et al. 04]



[Xu et al. 09]



[Laga et al. 13]



[Yang et al. 11]

# Overview

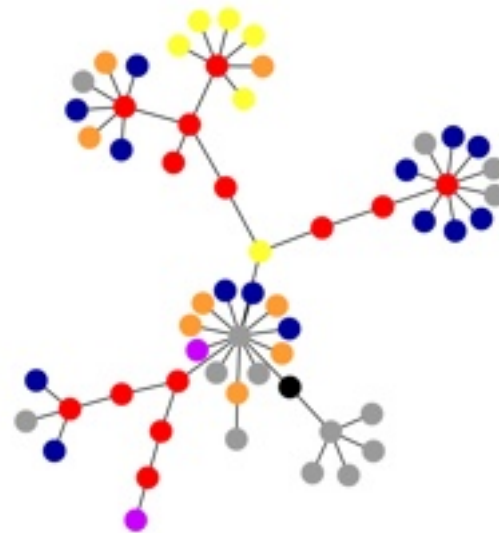
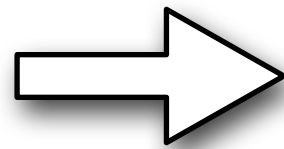
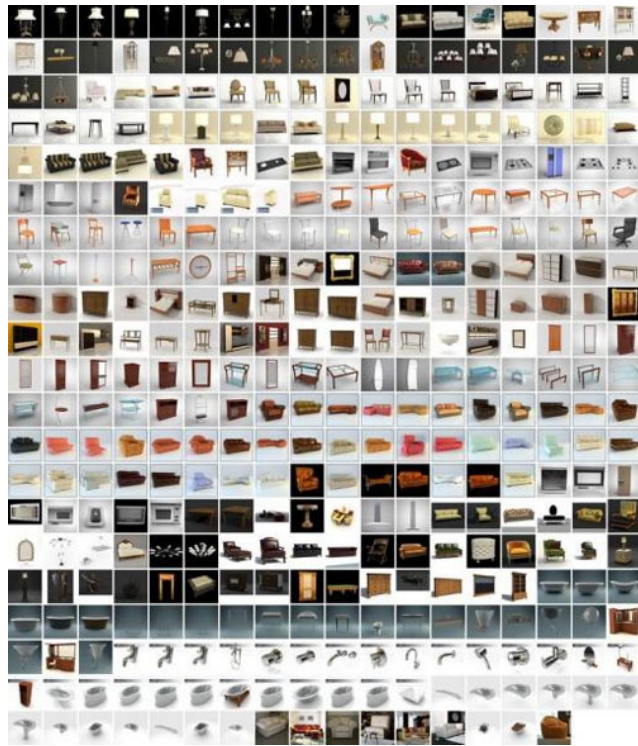
- Introduction
- ***Model of structure***
- Analysis
- Applications
- Conclusion and Future Challenges



# Structure-aware Shape Processing



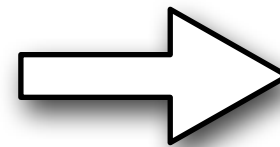
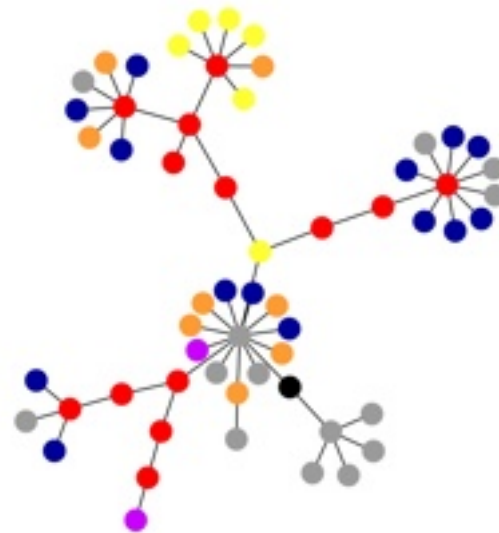
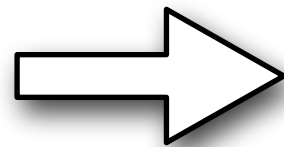
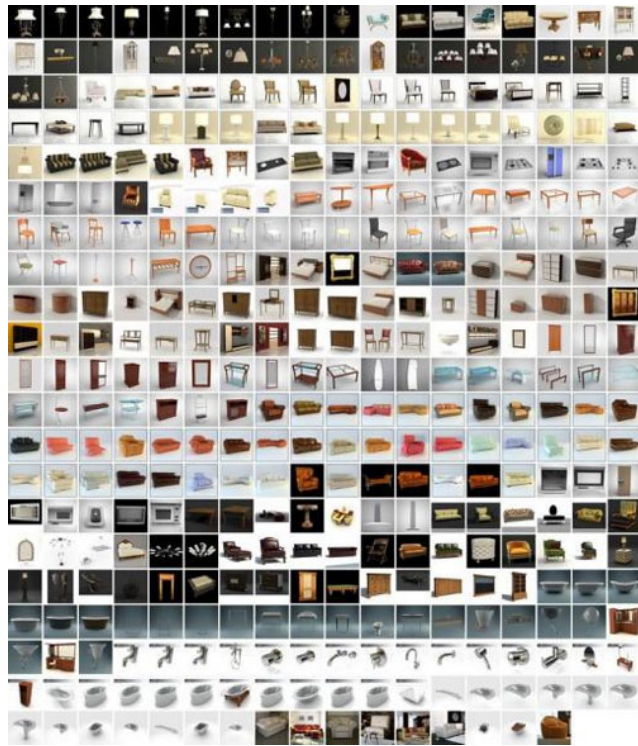
# Structure-aware Shape Processing



analysis



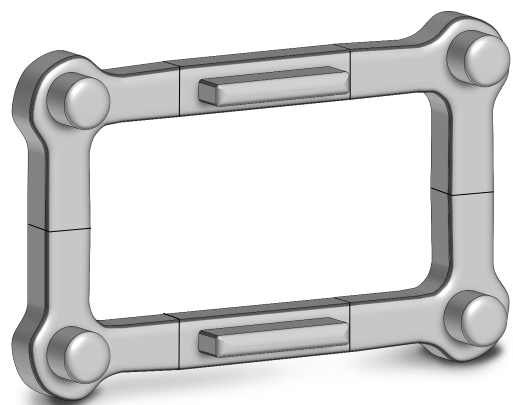
# Structure-aware Shape Processing



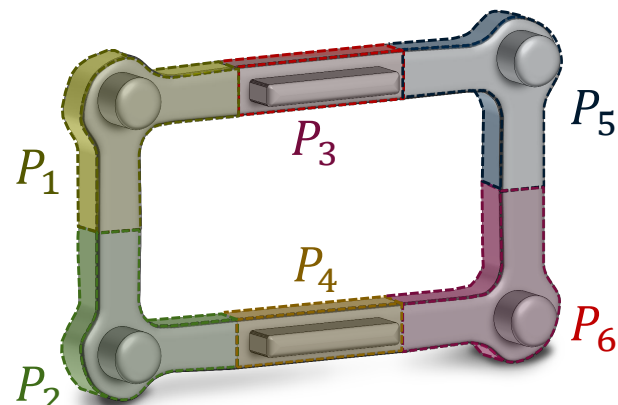
analysis

synthesis

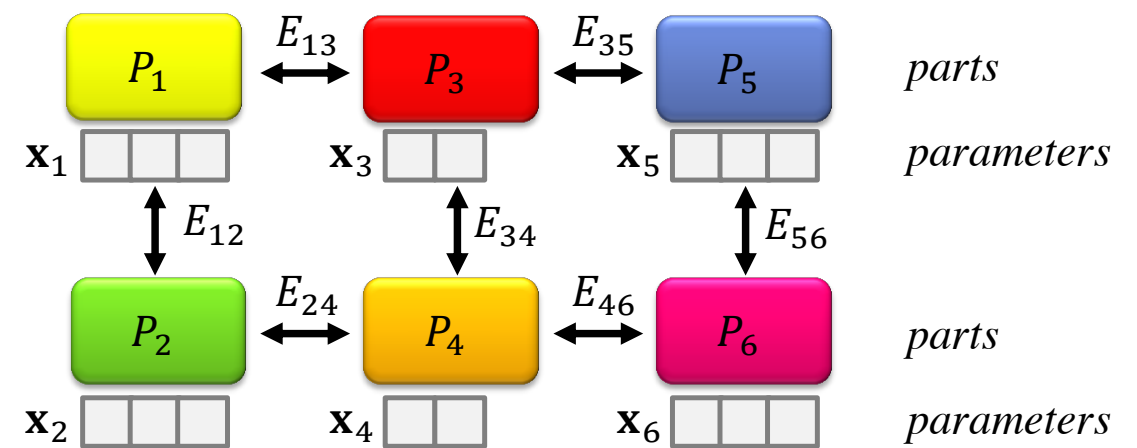
# Encoding Structure



(a) a piece of geometry  $\mathcal{S}$



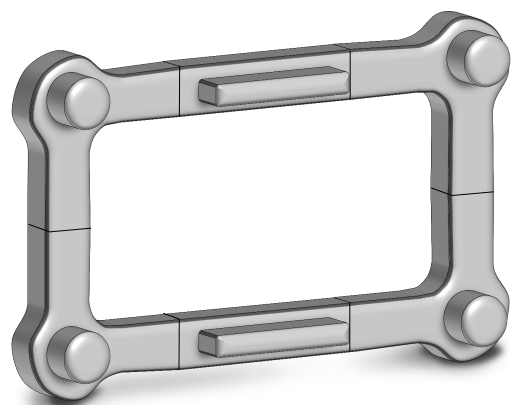
(b) parts and part geometry



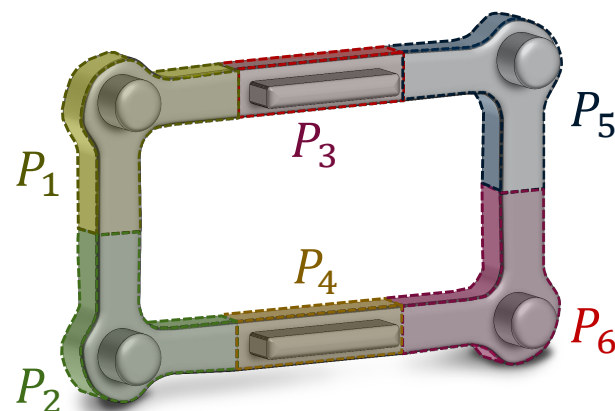
(c) parts, variables, and pairwise relations

# Encoding Structure

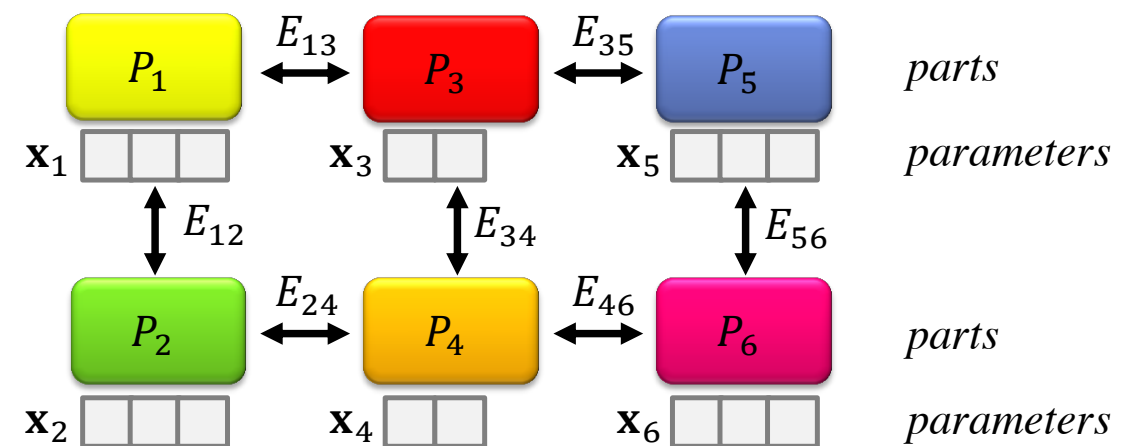
What are the parts?



(a) a piece of geometry  $\mathcal{S}$



(b) parts and part geometry

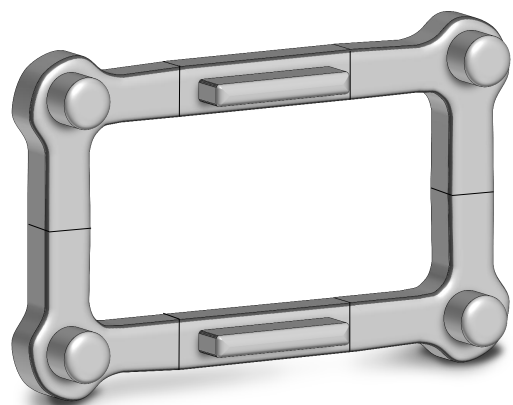


(c) parts, variables, and pairwise relations

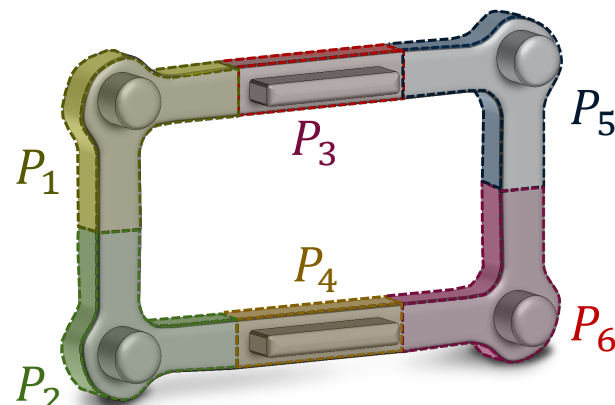
# Encoding Structure

What are the parts?

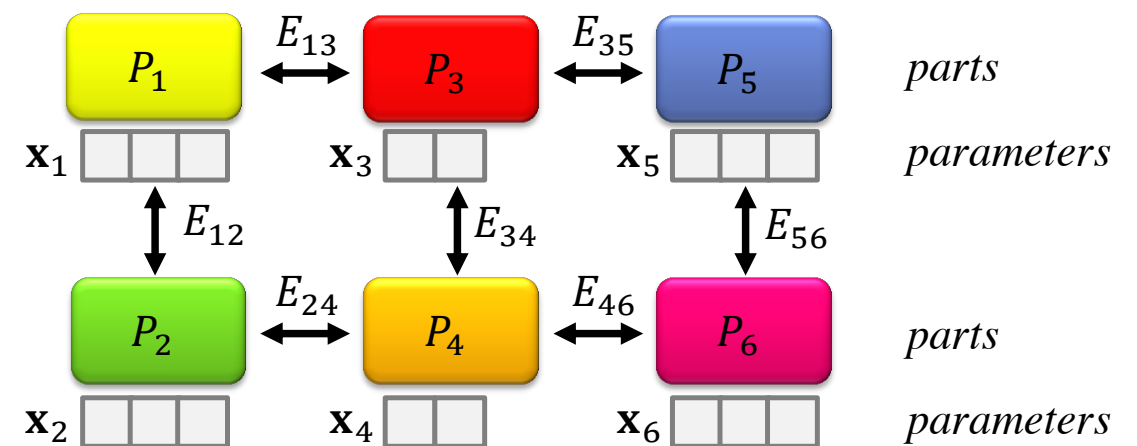
How do the parts relate in/across models?



(a) a piece of geometry  $\mathcal{S}$



(b) parts and part geometry



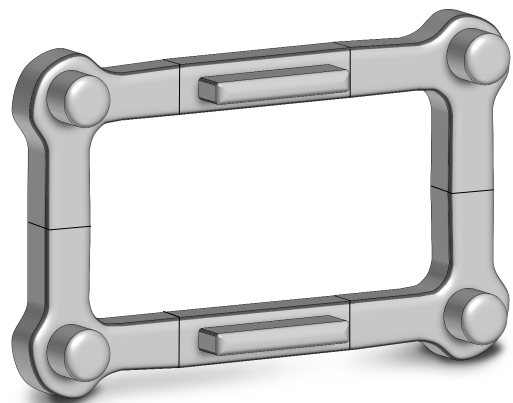
(c) parts, variables, and pairwise relations

# Encoding Structure

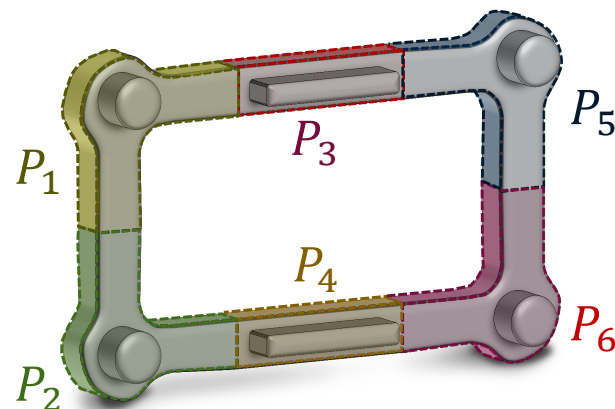
What are the parts?

How do the parts relate in/across models?

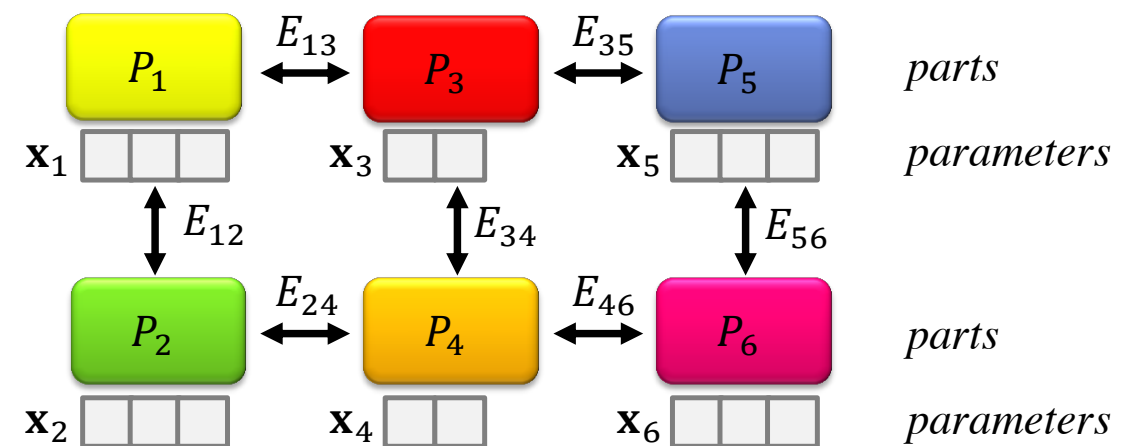
How do the parts vary across the models?



(a) a piece of geometry  $\mathcal{S}$



(b) parts and part geometry



(c) parts, variables, and pairwise relations

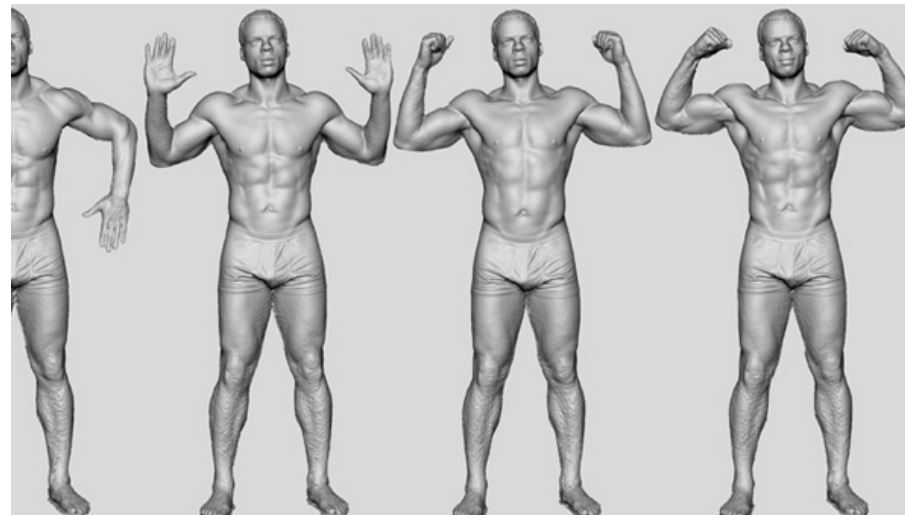
# New Sources of Data

# New Sources of Data



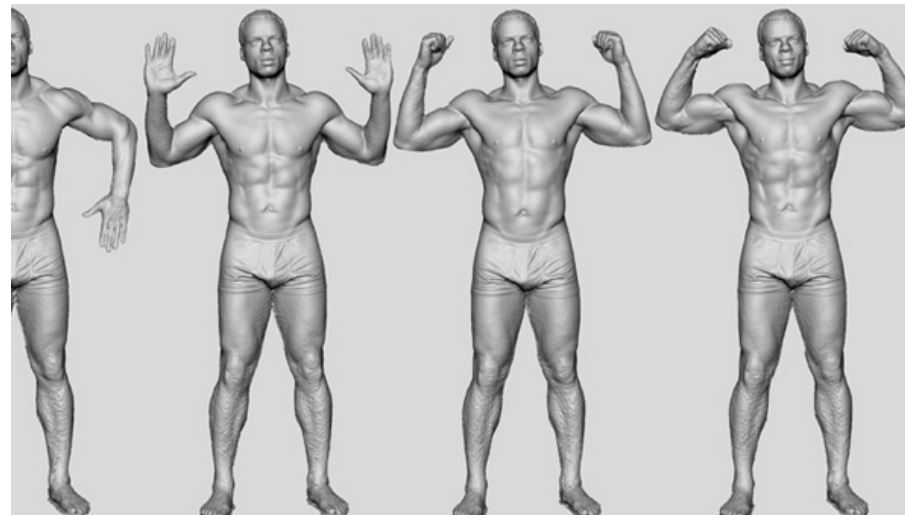


# New Sources of Data

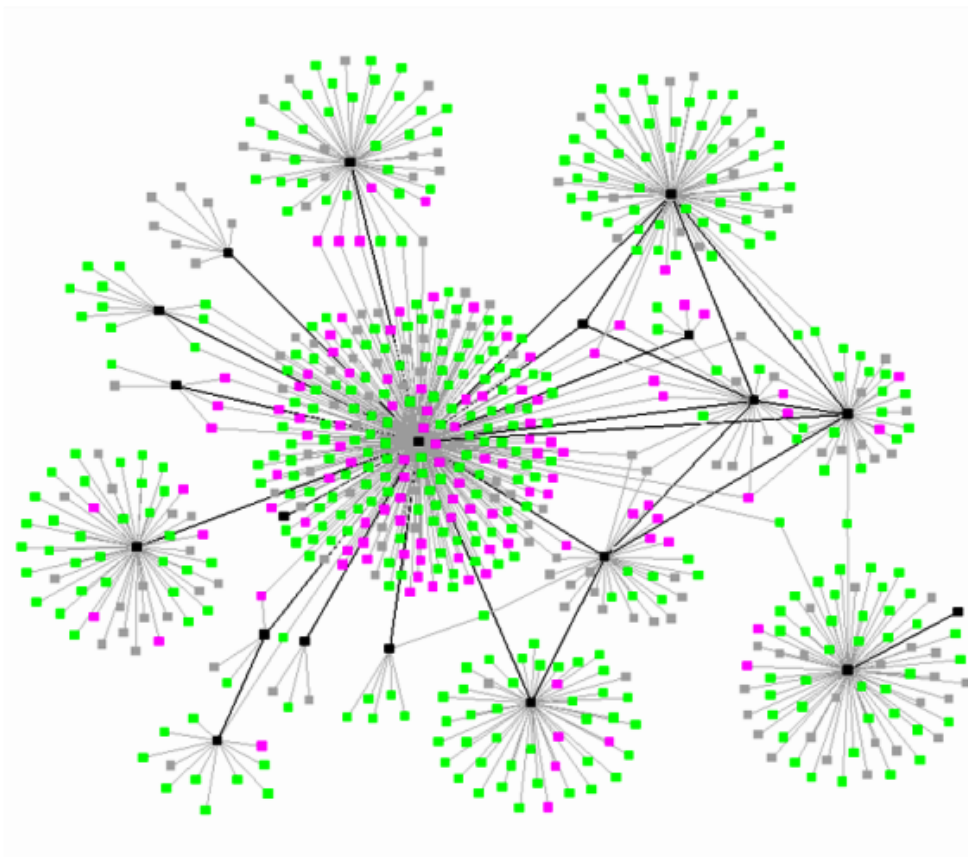
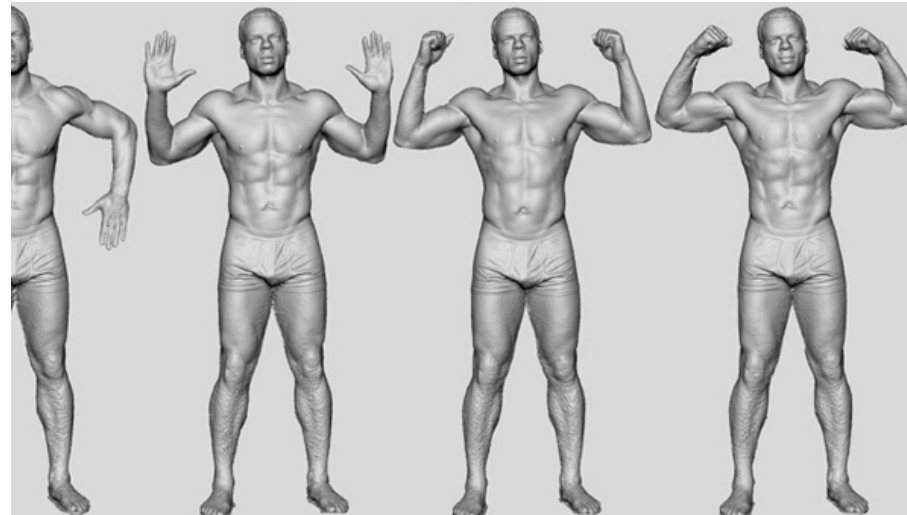




# New Sources of Data



# New Sources of Data



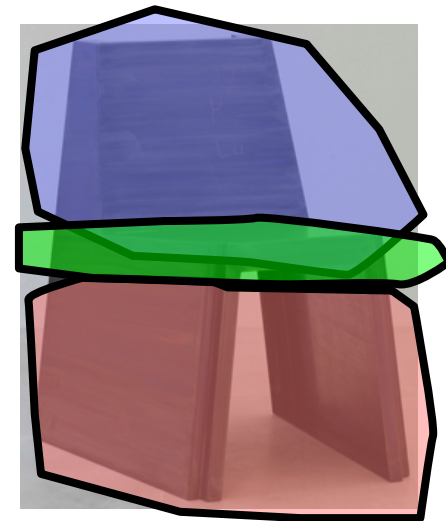
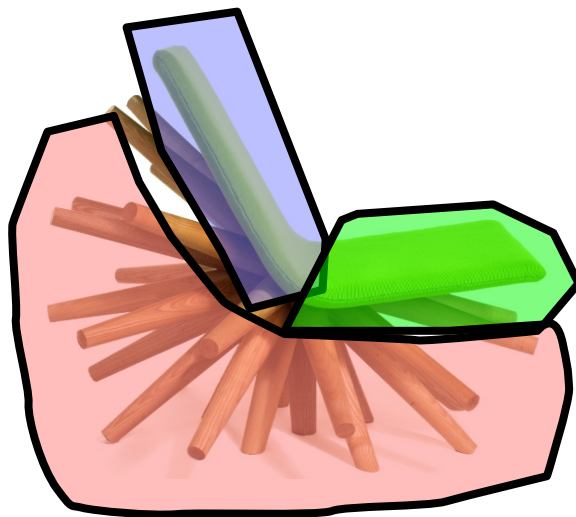
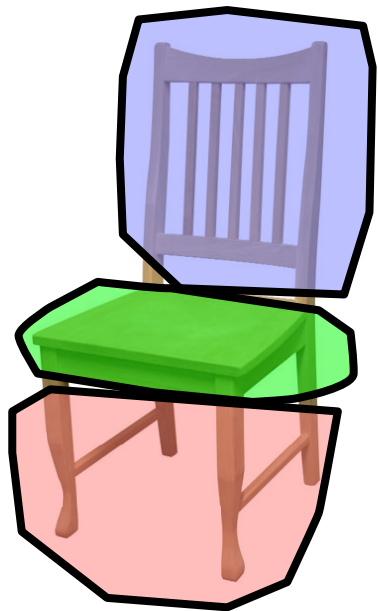
***network of parts***



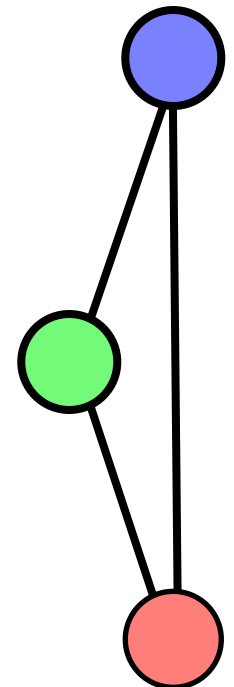
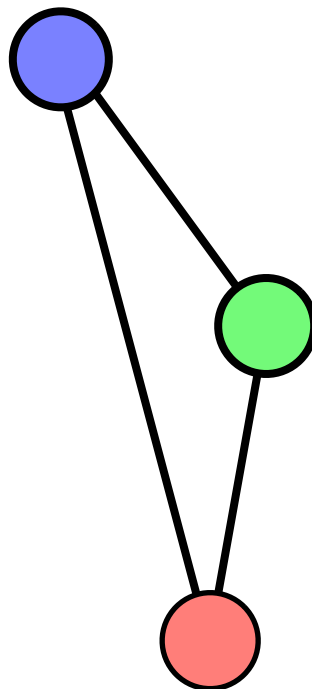
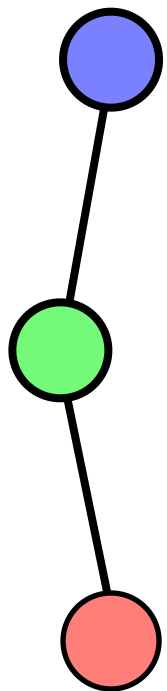
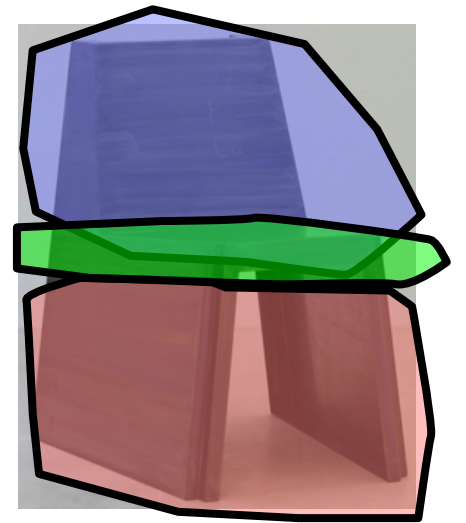
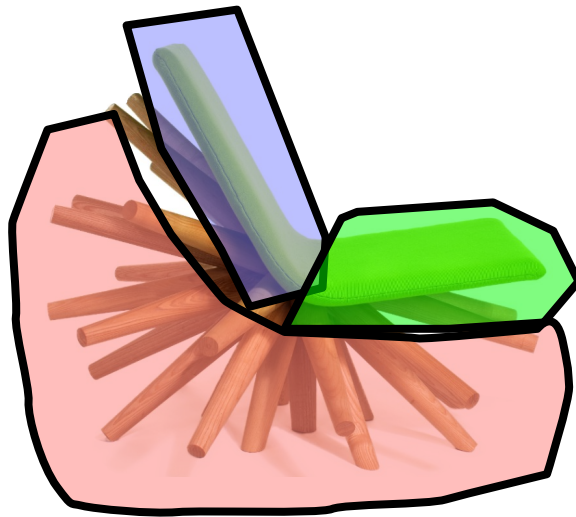
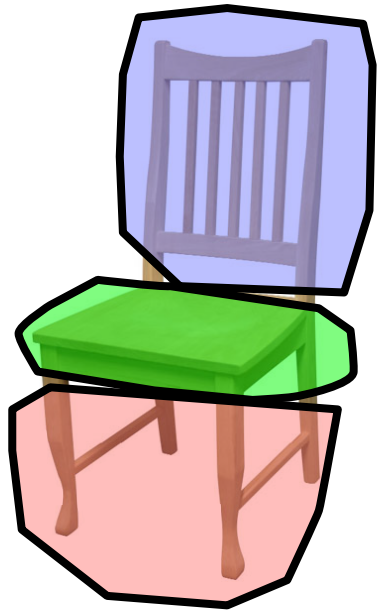
# Why Structures?



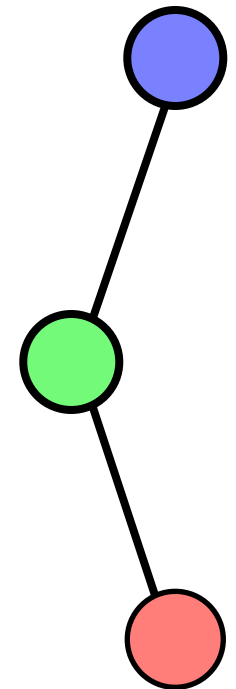
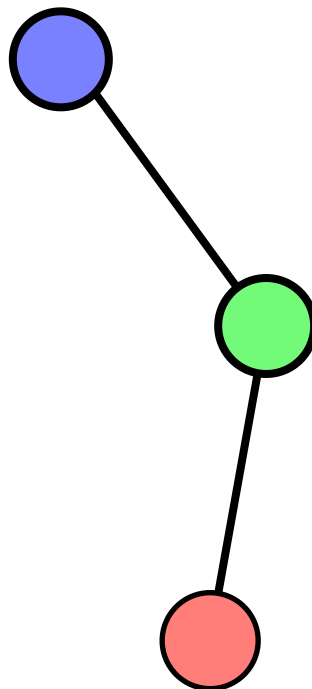
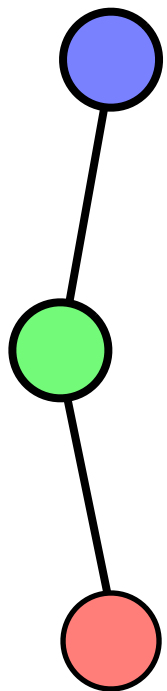
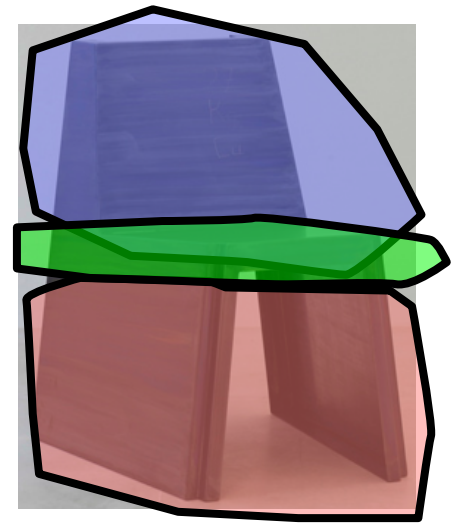
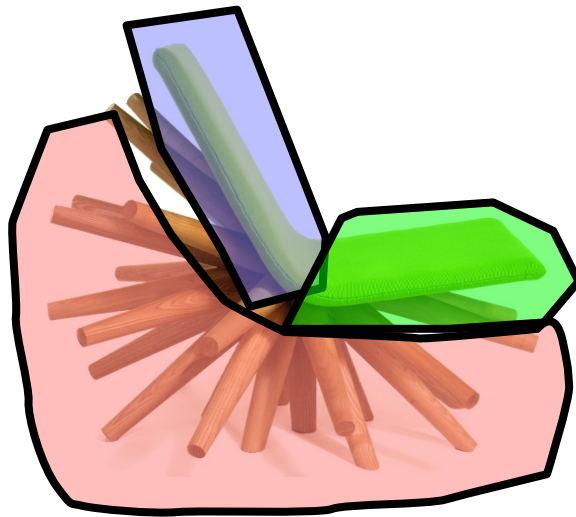
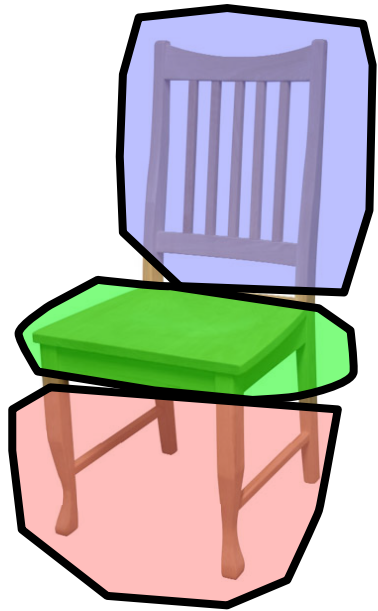
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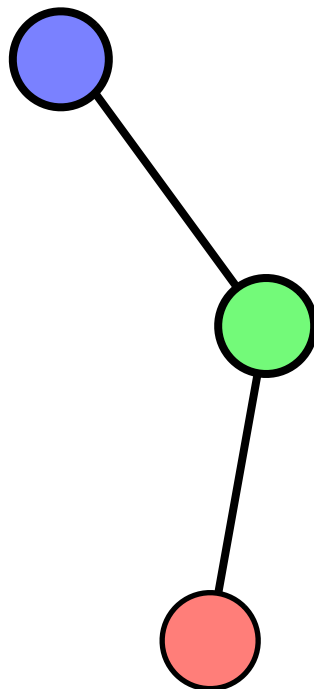
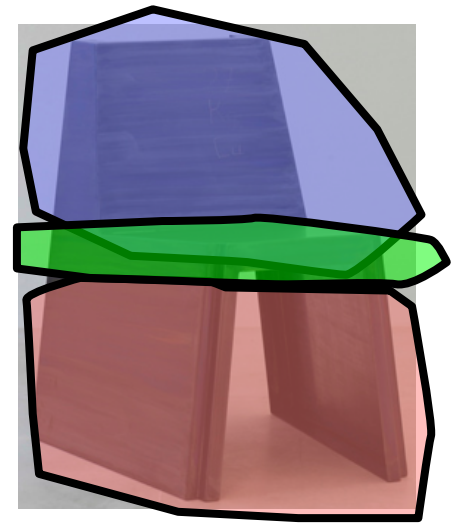
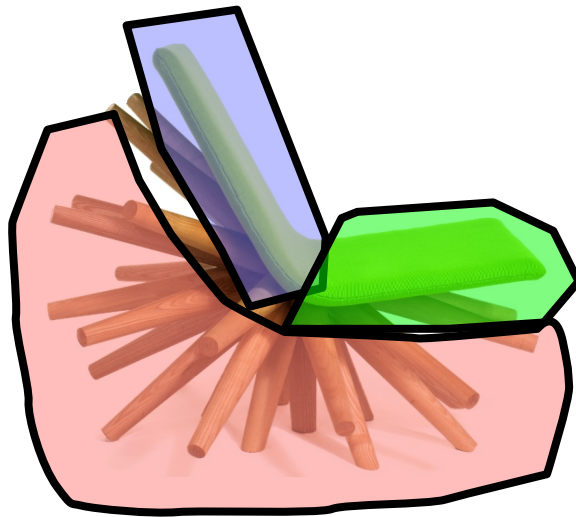
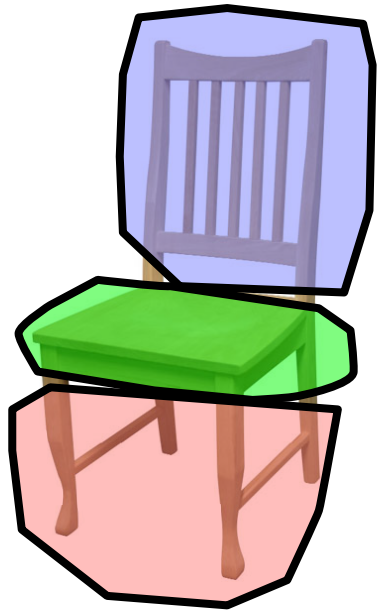
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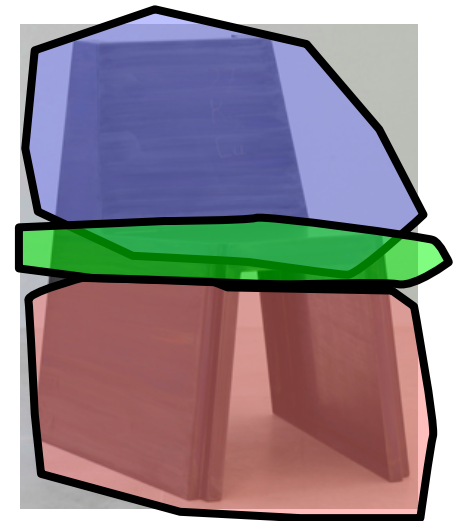
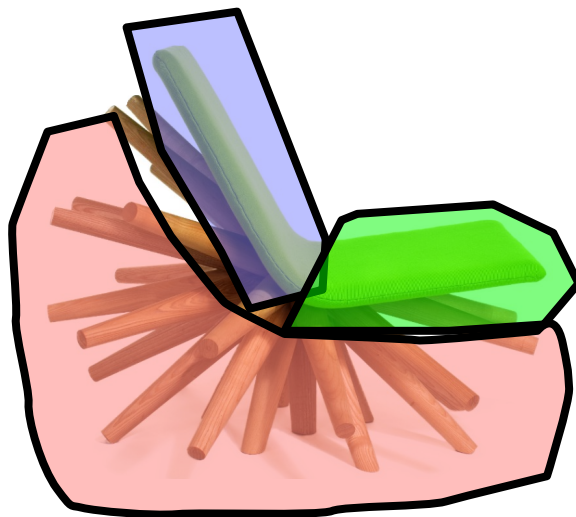
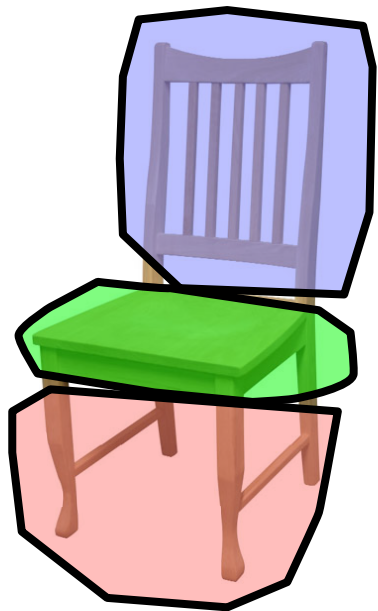
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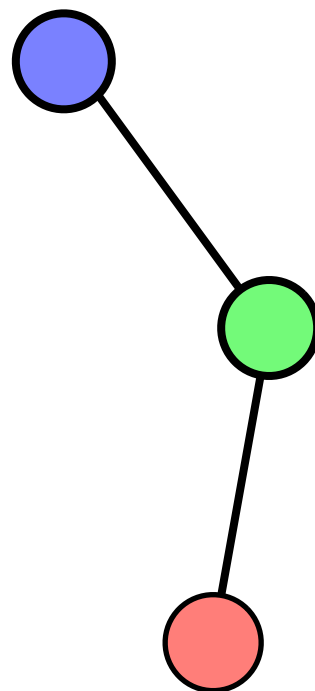
# Why Structures?



# Why Structures?



*relation graph + variations ~ captures semantics?*





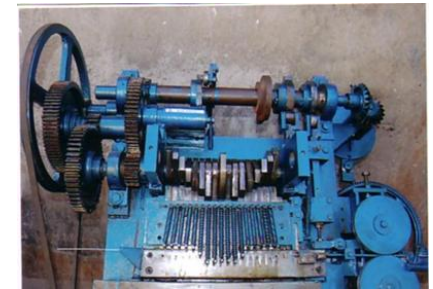
# Overview

- Introduction
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- ***Analysis***
- Applications
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# Historical Perspective

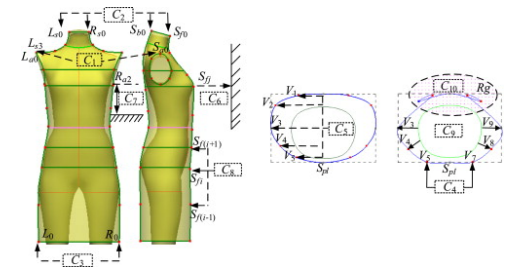
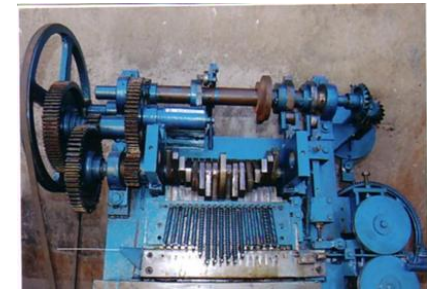
# Historical Perspective

- Mechanical assemblies



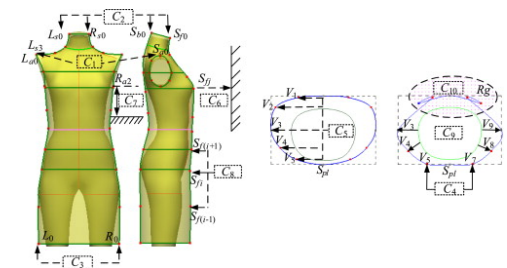
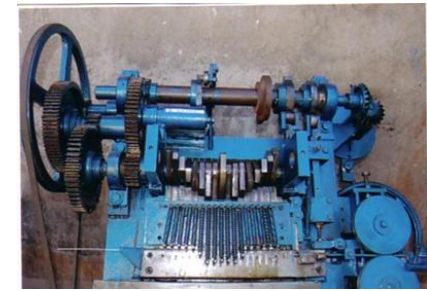
# Historical Perspective

- Mechanical assemblies
- CAD community: constrained editing



# Historical Perspective

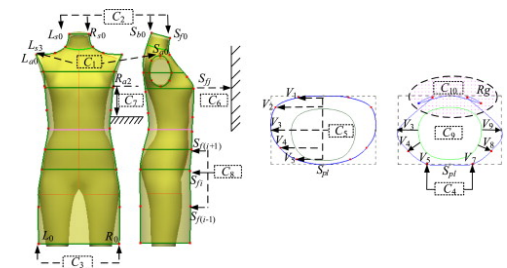
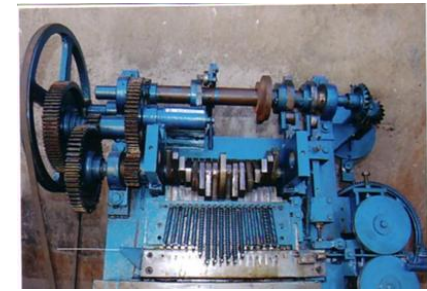
- Mechanical assemblies
- CAD community: constrained editing
- Compositional modeling





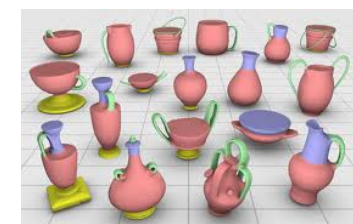
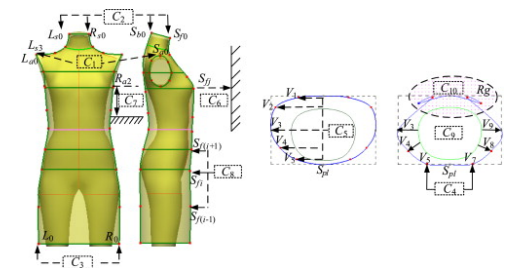
# Historical Perspective

- Mechanical assemblies
- CAD community: constrained editing
- Compositional modeling
- Symmetry analysis



# Historical Perspective

- Mechanical assemblies
- CAD community: constrained editing
- Compositional modeling
- Symmetry analysis
- Co-analysis of model collections, etc.



# Discovering Structure

# Discovering Structure

What are the parts (and their parameters)?

*Segmentation*

# Discovering Structure

What are the parts (and their parameters)?

*Segmentation*

How do the parts relate in/across models?

*Correspondence*



# Discovering Structure

What are the parts (and their parameters)?

*Segmentation*

How do the parts relate in/across models?

*Correspondence*

How do the parts vary across the models?

*Deformation*

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(e.g., classifiers on labeled parts)



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(e.g., spectral clustering)

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# Overview

- Introduction
- Model of structure
- Analysis
- ***Applications***
- Conclusion and Future Challenges

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*slides, supplementary on project page*