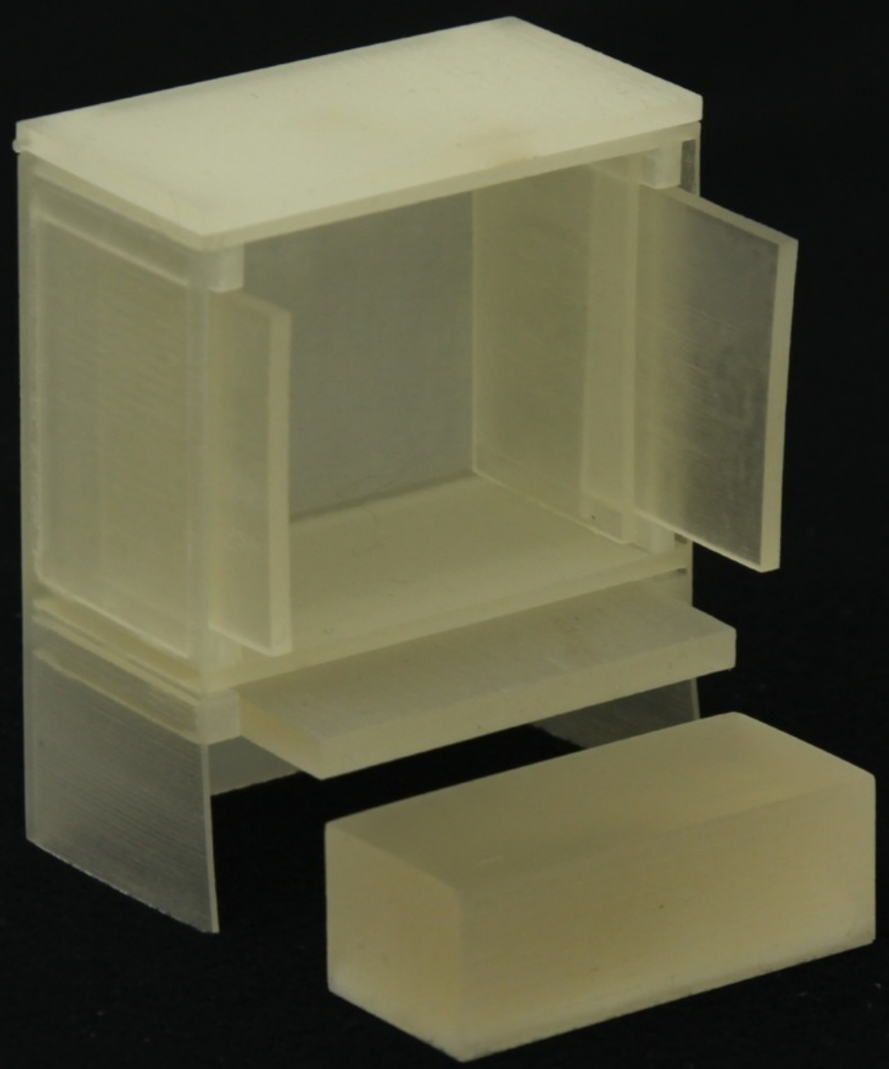
Creating Works-like Prototypes of Mechanical Objects

Bongjin Koo[1] Wilmot Li[2] JiaXian Yao[3] Maneesh Agrawala[3] Niloy J. Mitra[1]

[1]University College London [2]Adobe Research [3]UC Berkeley

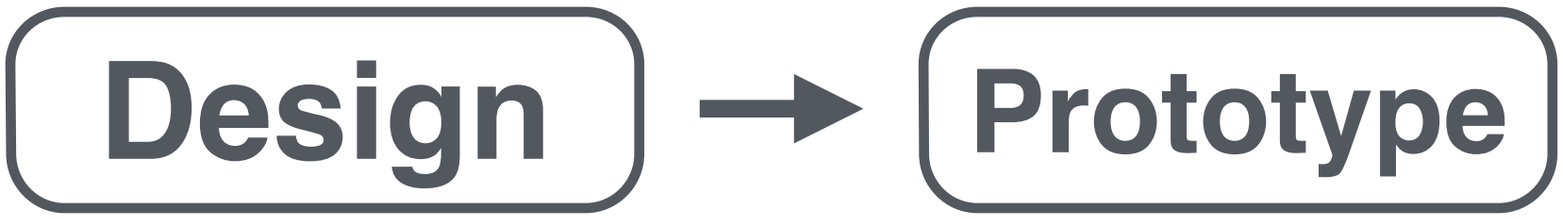


SIGGRAPH ASIA 2014 SHENZHEN

Design process example

Design

Design process example



Design process example

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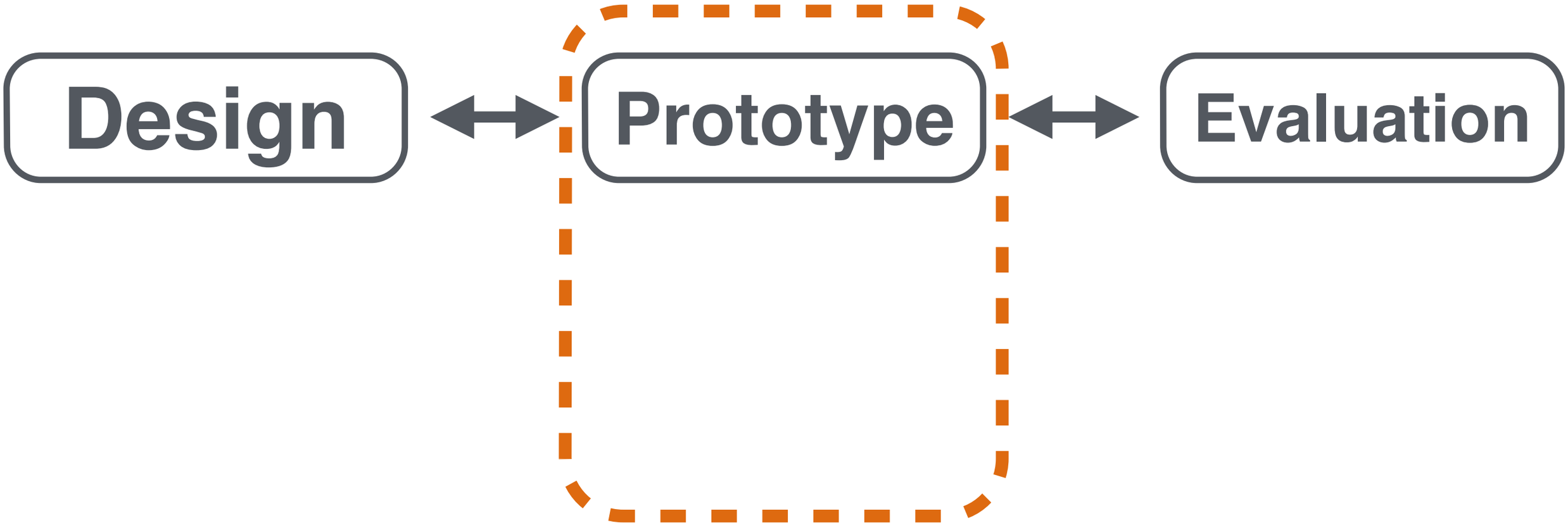
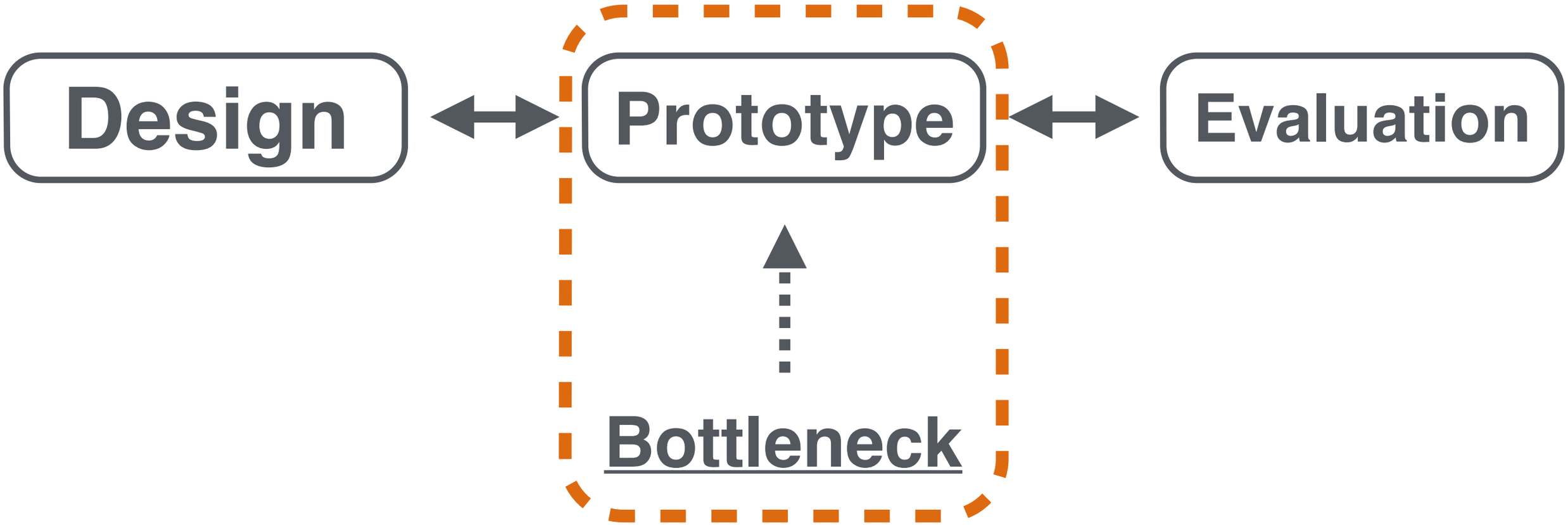


Design process example



Works-like prototypes

Many iterations

Contributions

Identified useful **high-level functional relationships**

Contributions

Identified useful **high-level functional relationships**

Interactive tool for creating works-like prototypes

Proposed system

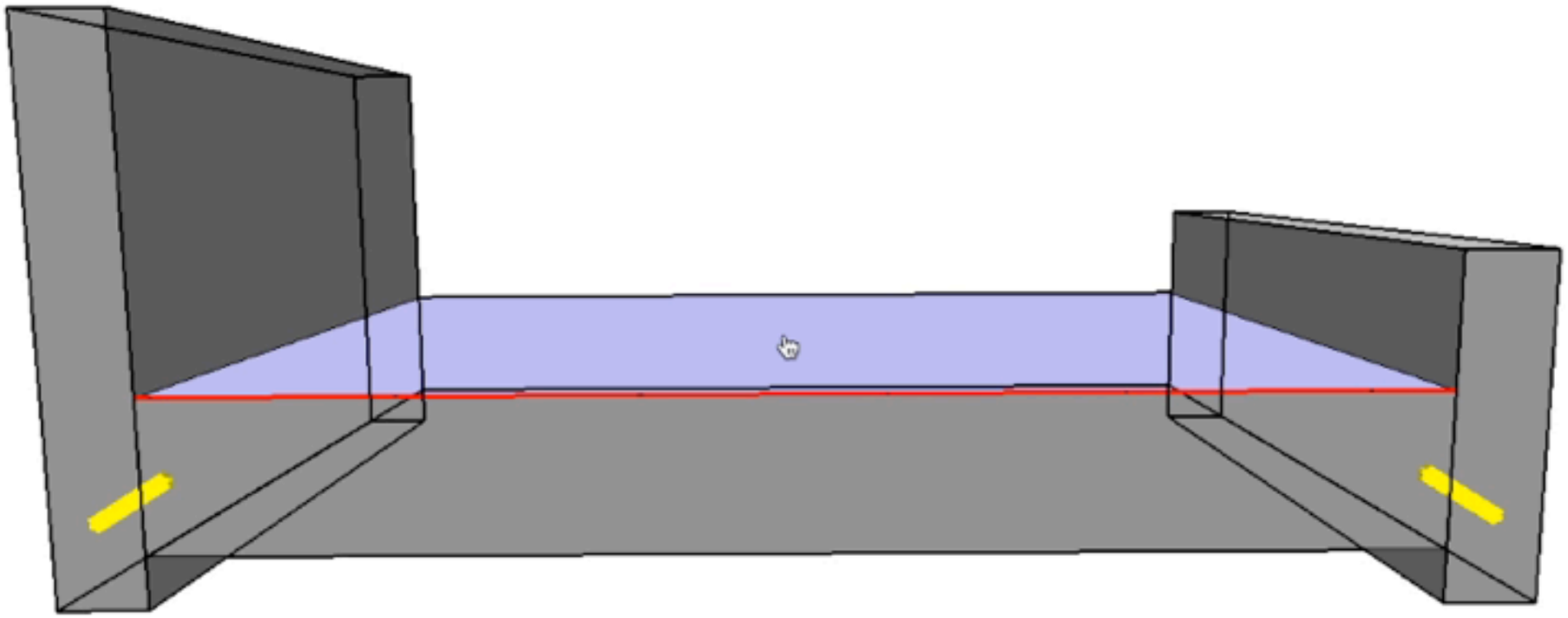
[redacted]

Proposed system

[redacted]

Proposed system

[redacted]



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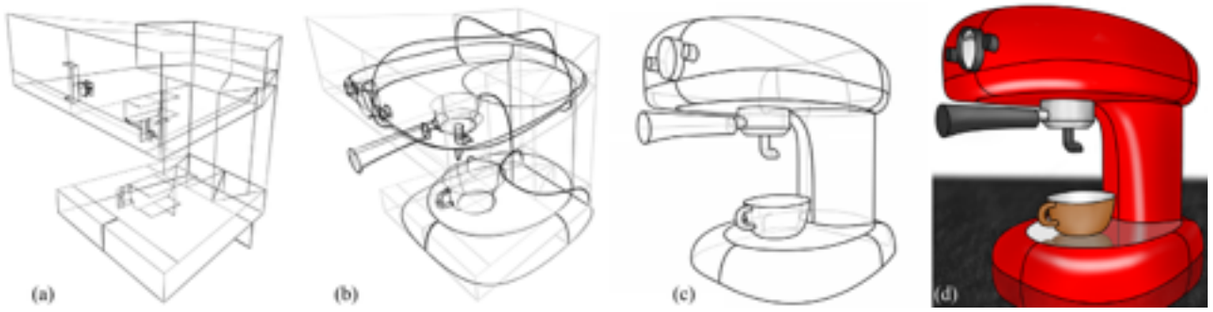
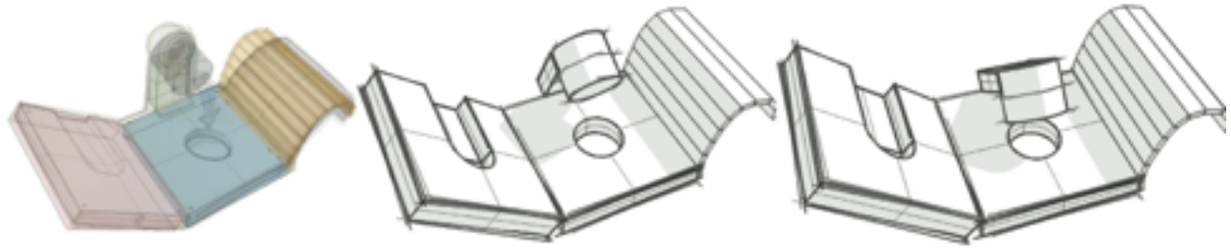
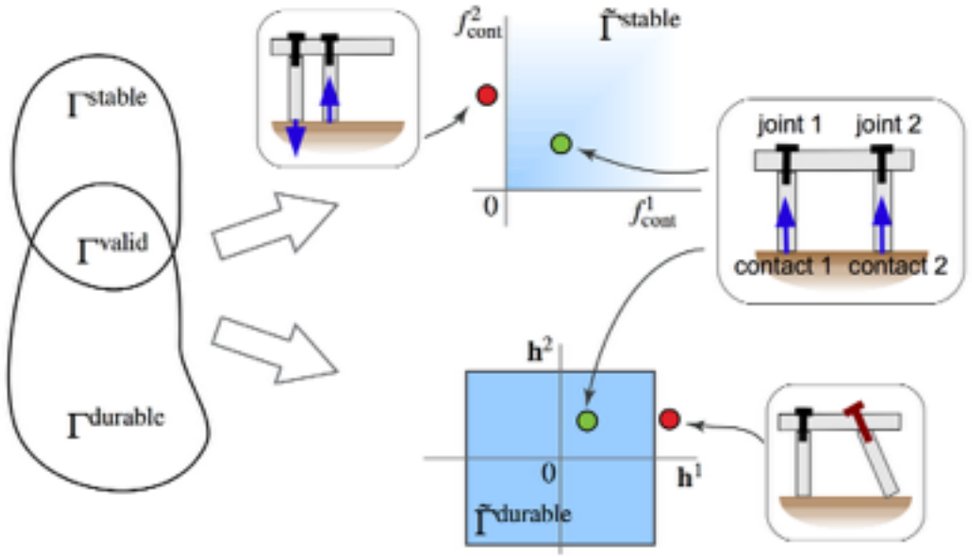
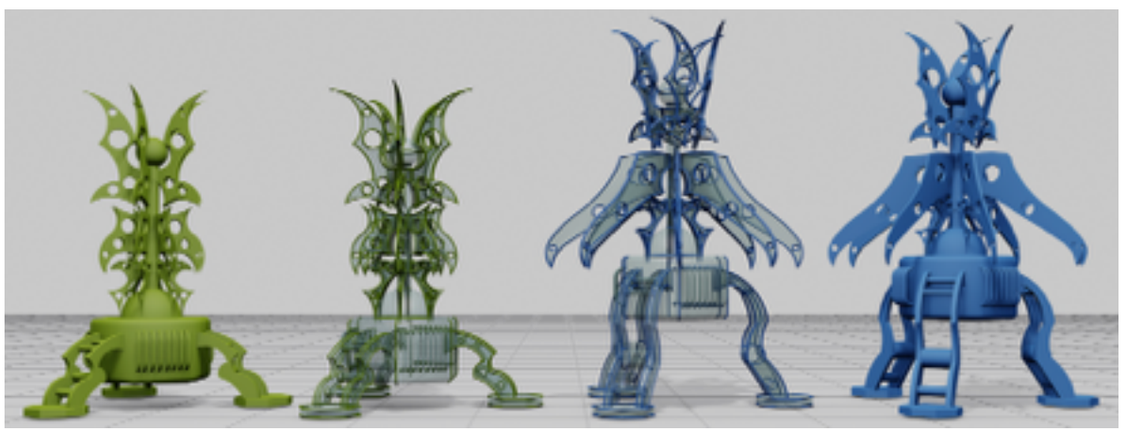
Related work









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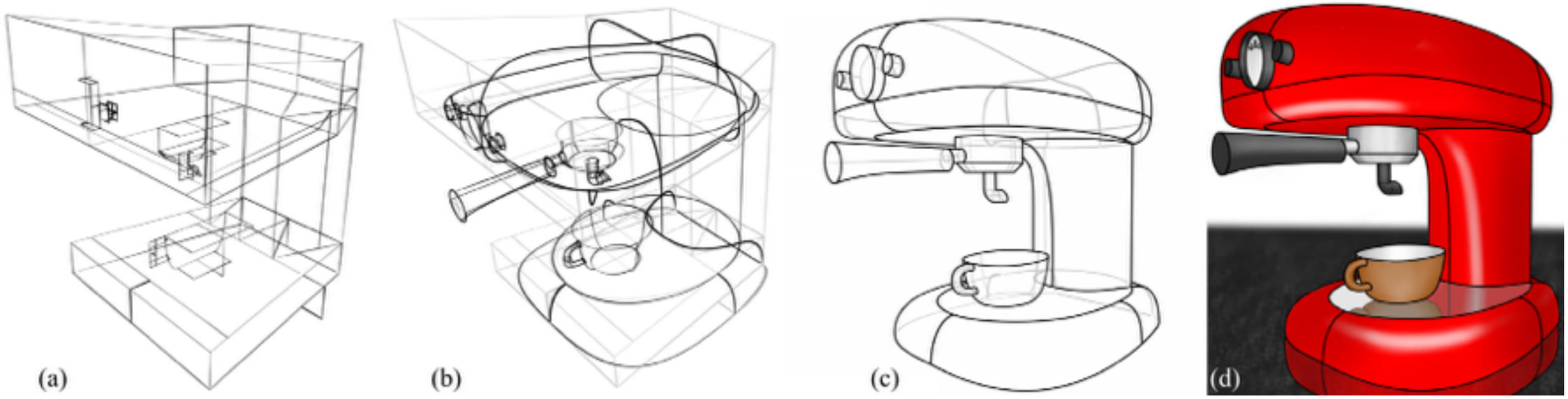
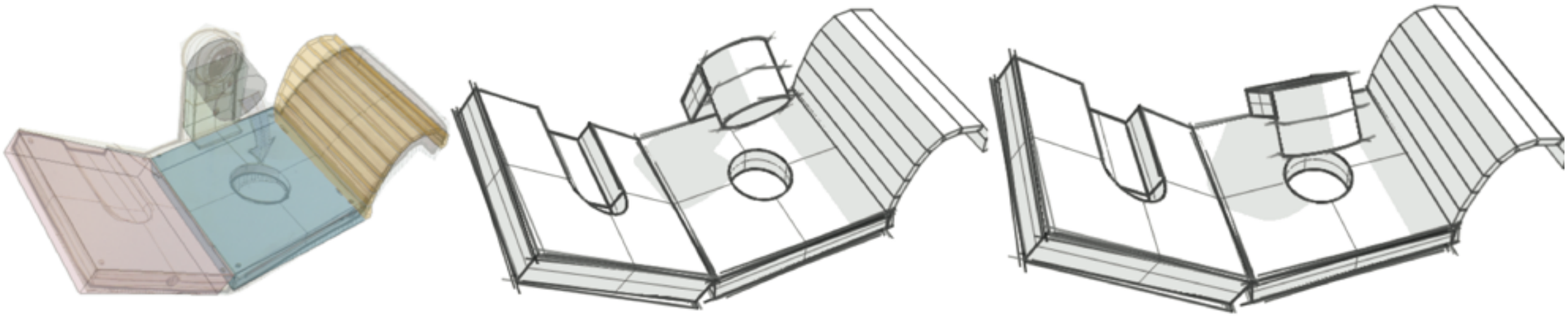


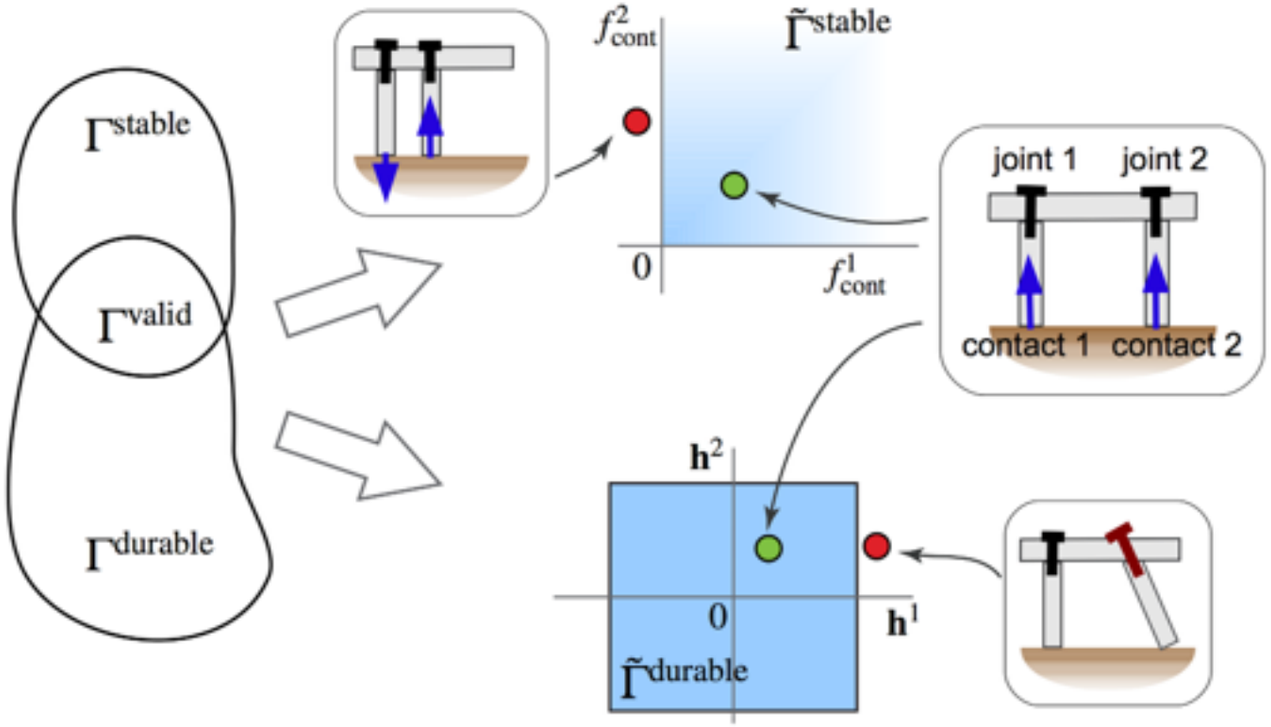
Schmidt et al. 2009



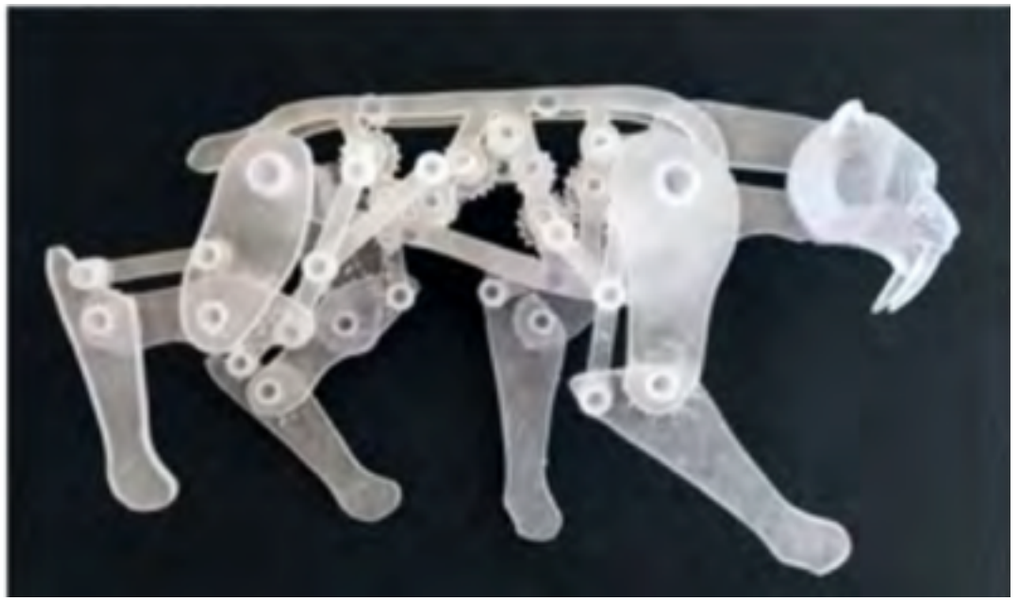
Shao et al. 2013

Bae et al. 2008, Shao et al. 2012, Xu et al. 2014

2. Tools for digital fabrication



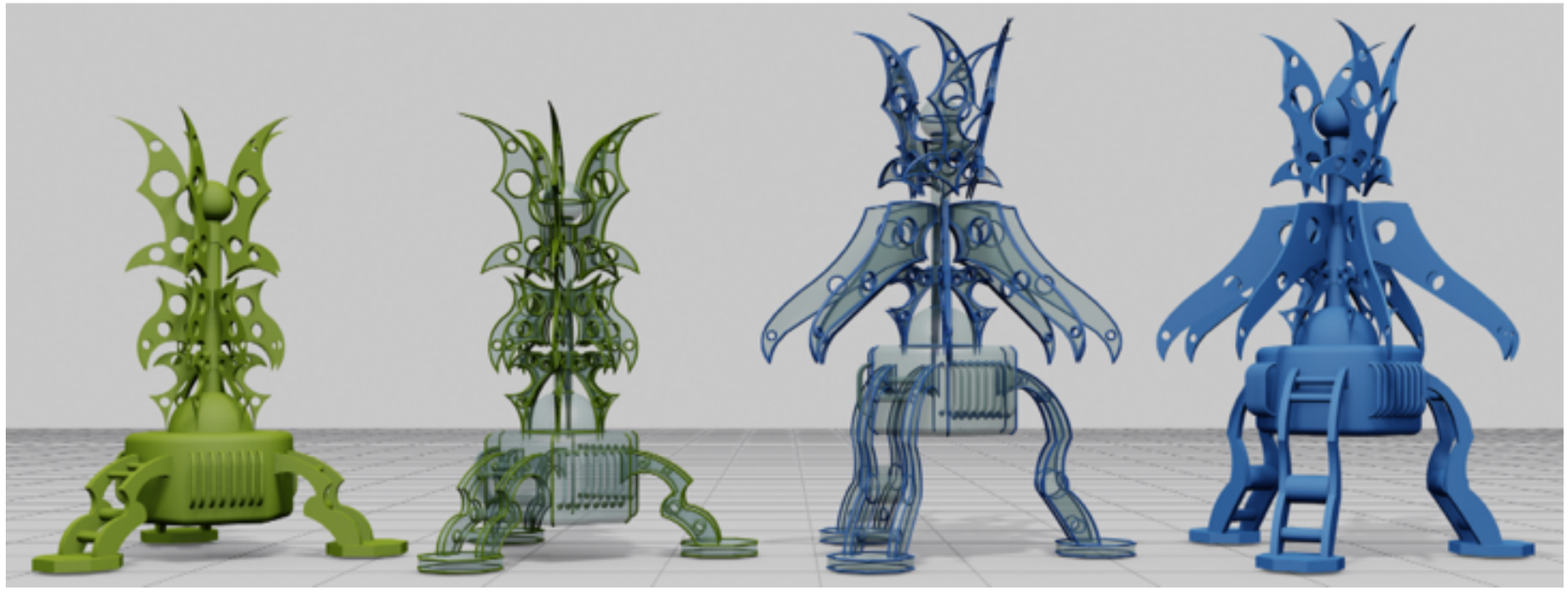
Umetani et al. 2012



Coros et al. 2013

Bächer et al. 2012, Calì et al. 2012, Stava et al. 2012, Zhu et al. 2012,
Ceylan et al. 2013, Prévost et al. 2013

3. Constraint-based modelling



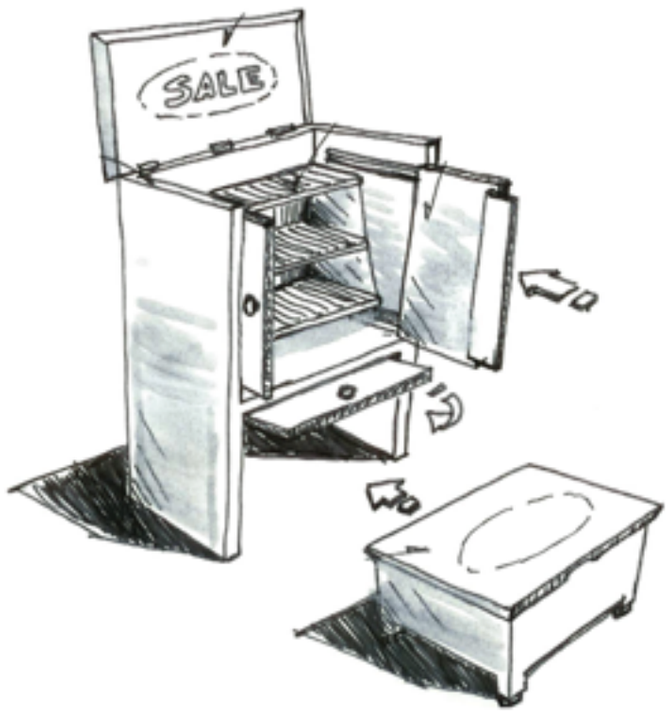
Gal et al. 2009

Xu et al. 2009

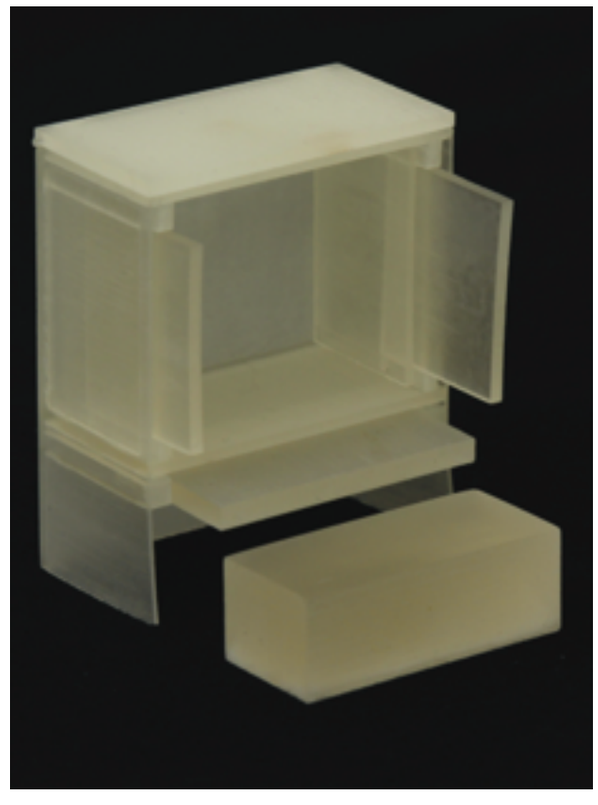
Daniel and Lucas 1997, Yvars 2008, Bokeloh et al. 2012, Zheng et al. 2012

Overview

Input

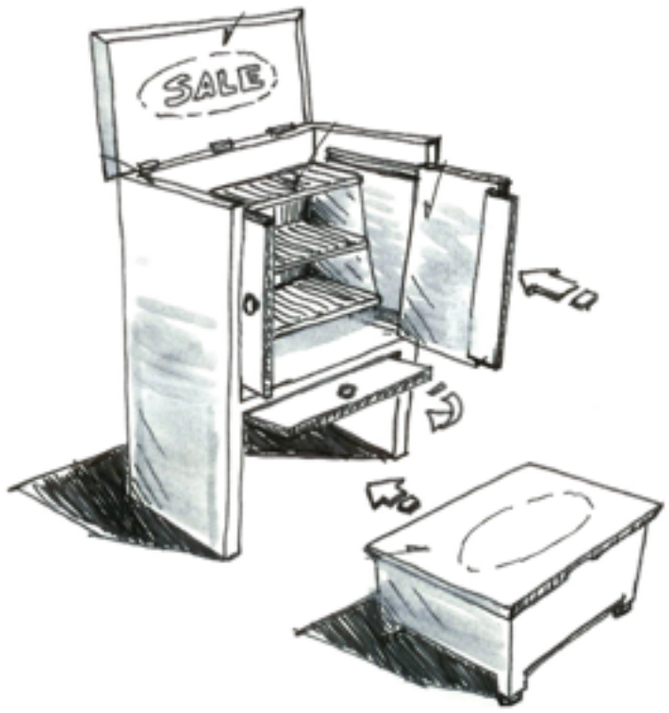


Output

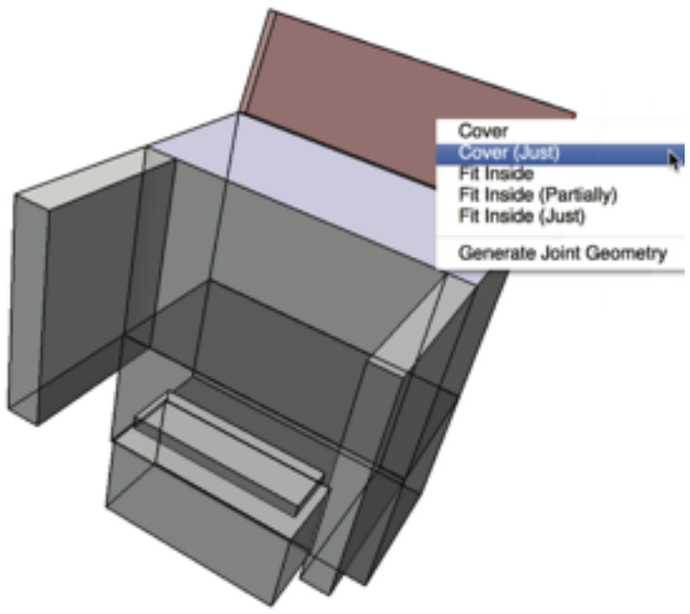


Overview

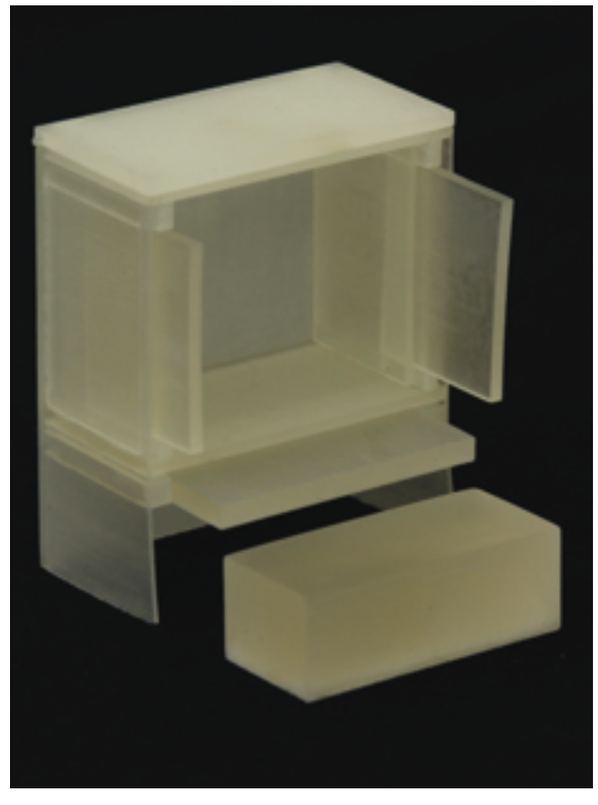
Input



1. Constraints

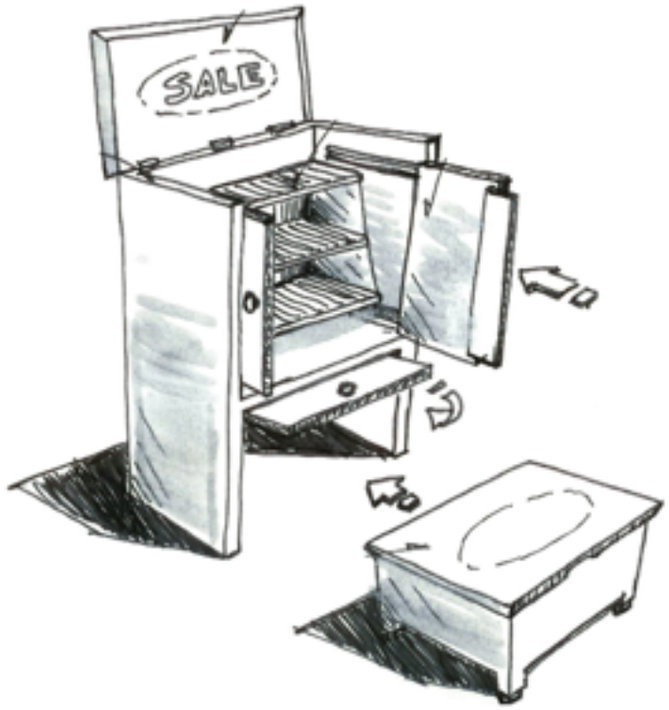


Output

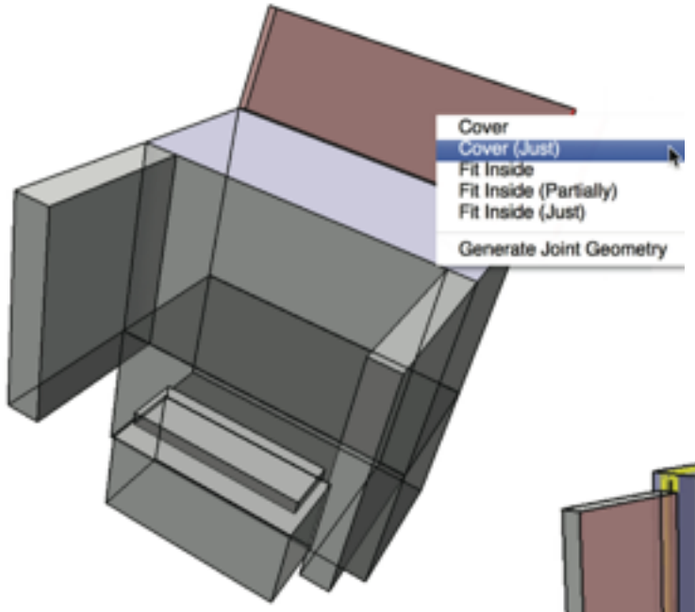


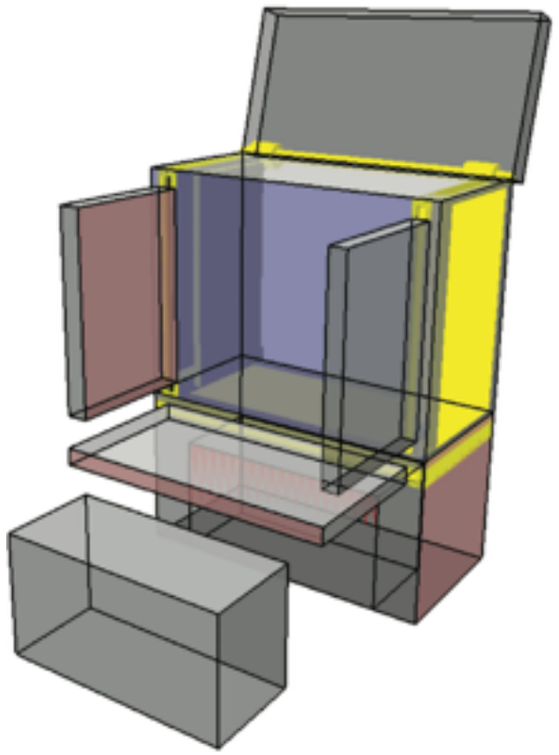
Overview

Input



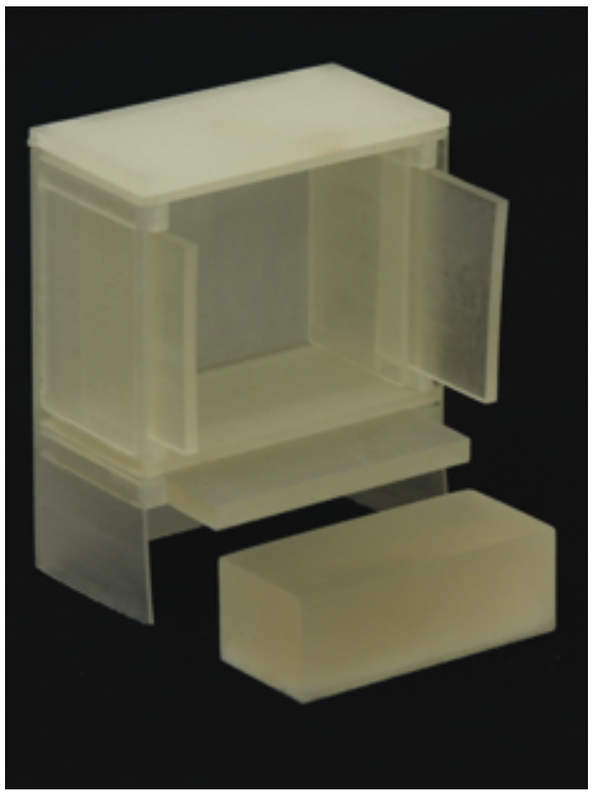
1. Constraints





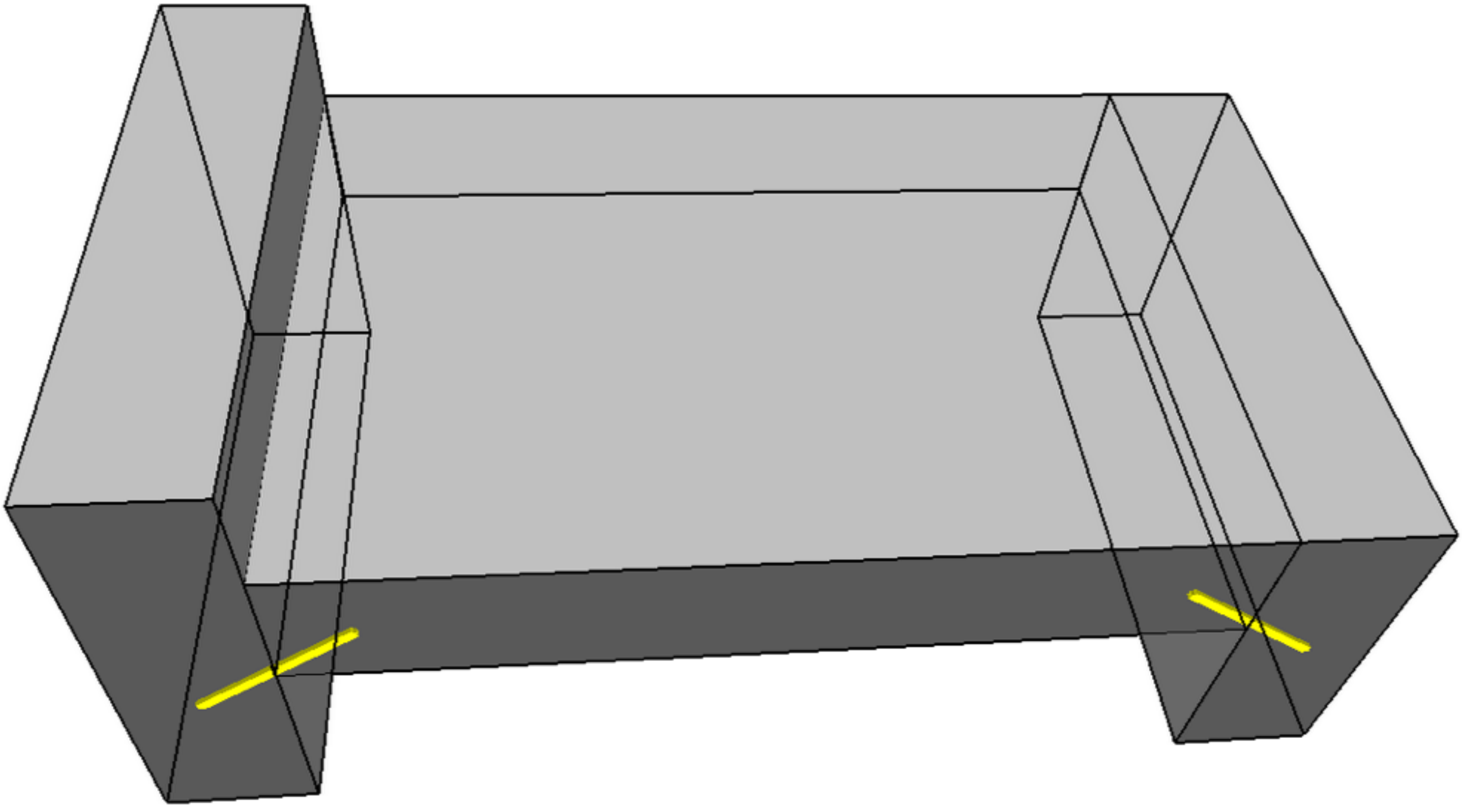
2. Optimisation

Output



Parts

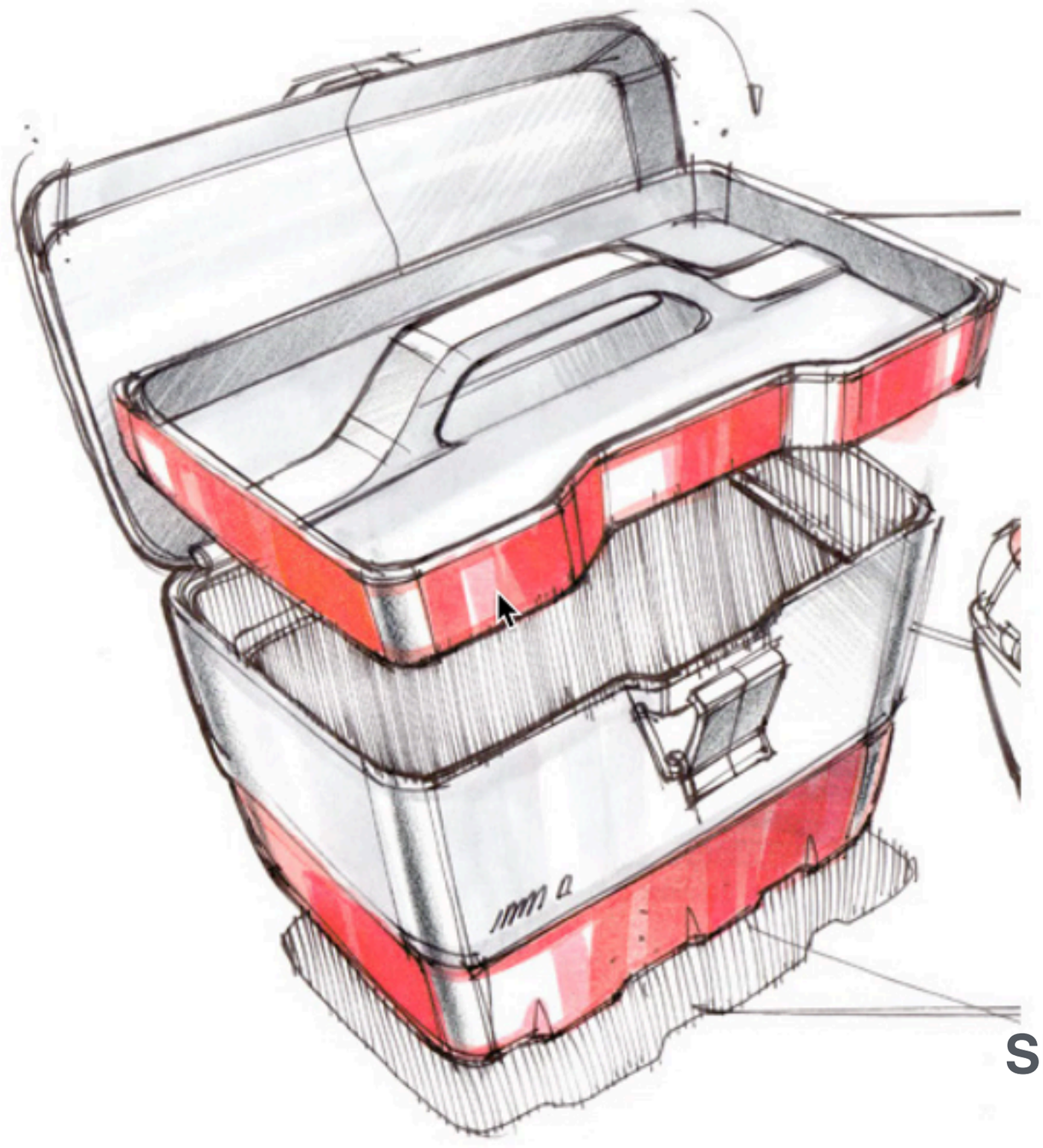
Axis-aligned cuboids



Generating parts

Generating parts

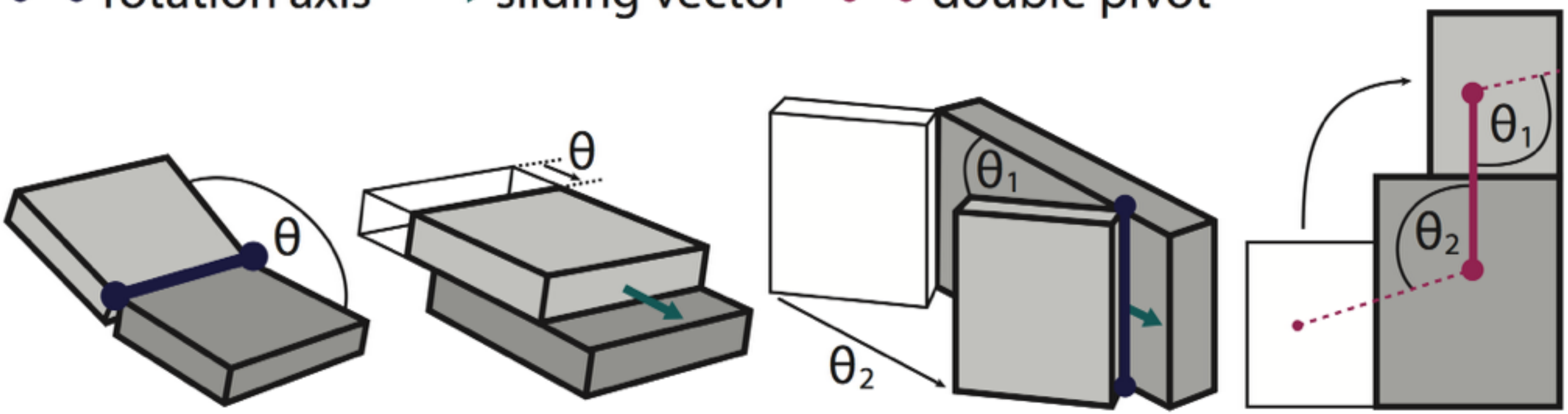
Generating parts



Shao et al. 2013

Joints

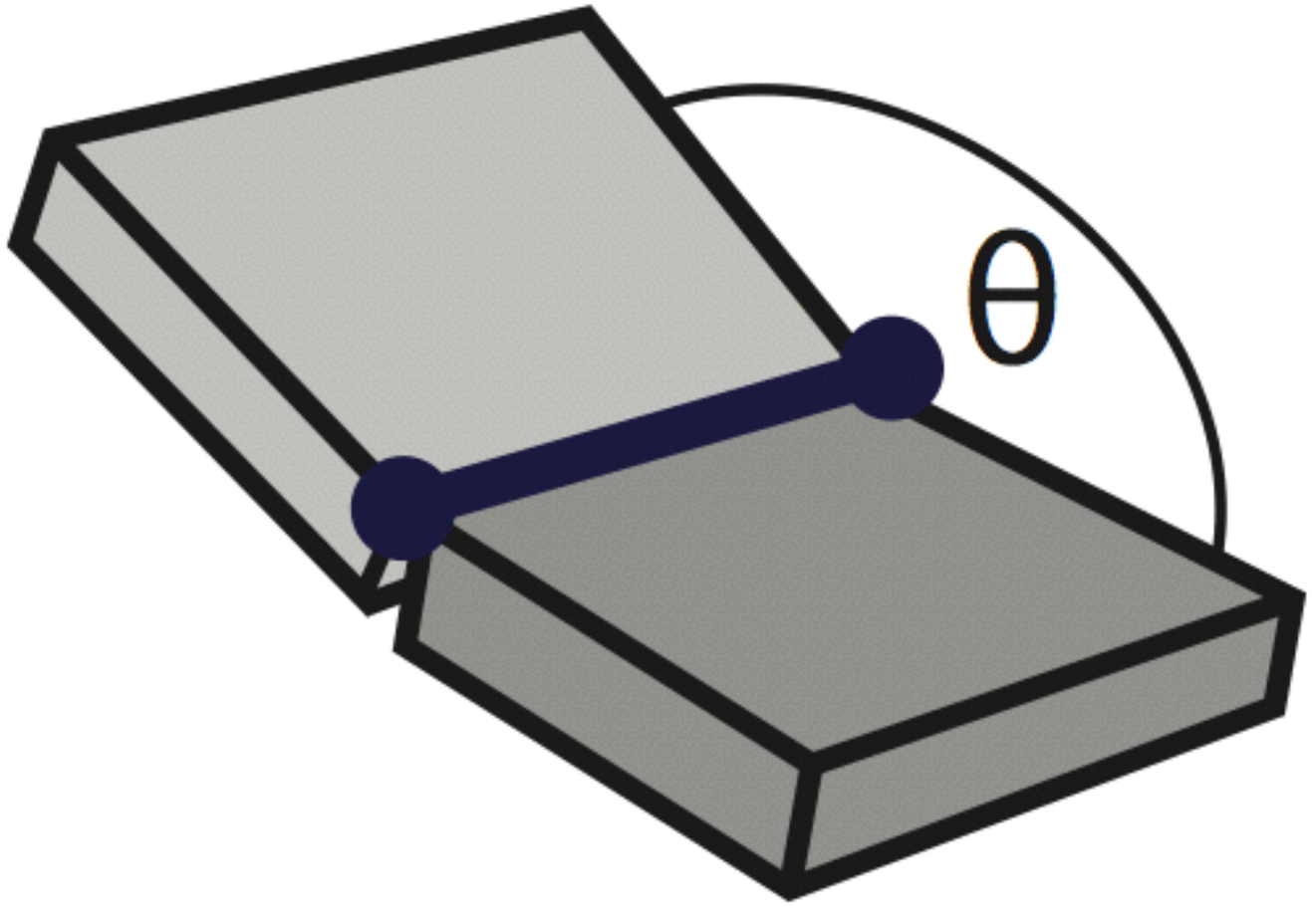
rotation axis sliding vector double pivot



(a) hinge (b) sliding joint (c) sliding hinge (d) double pivot

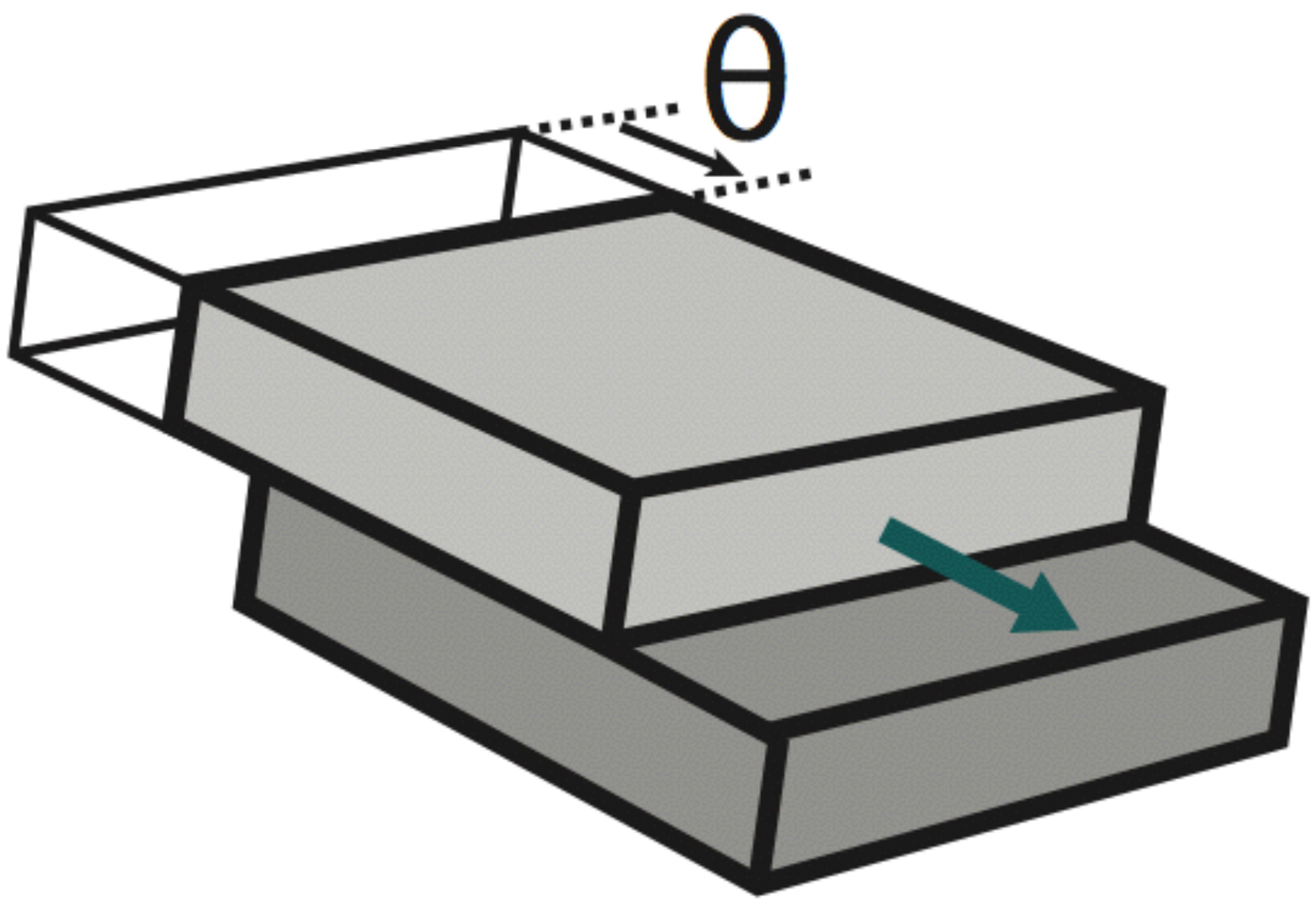
1. Hinge

rotation axis



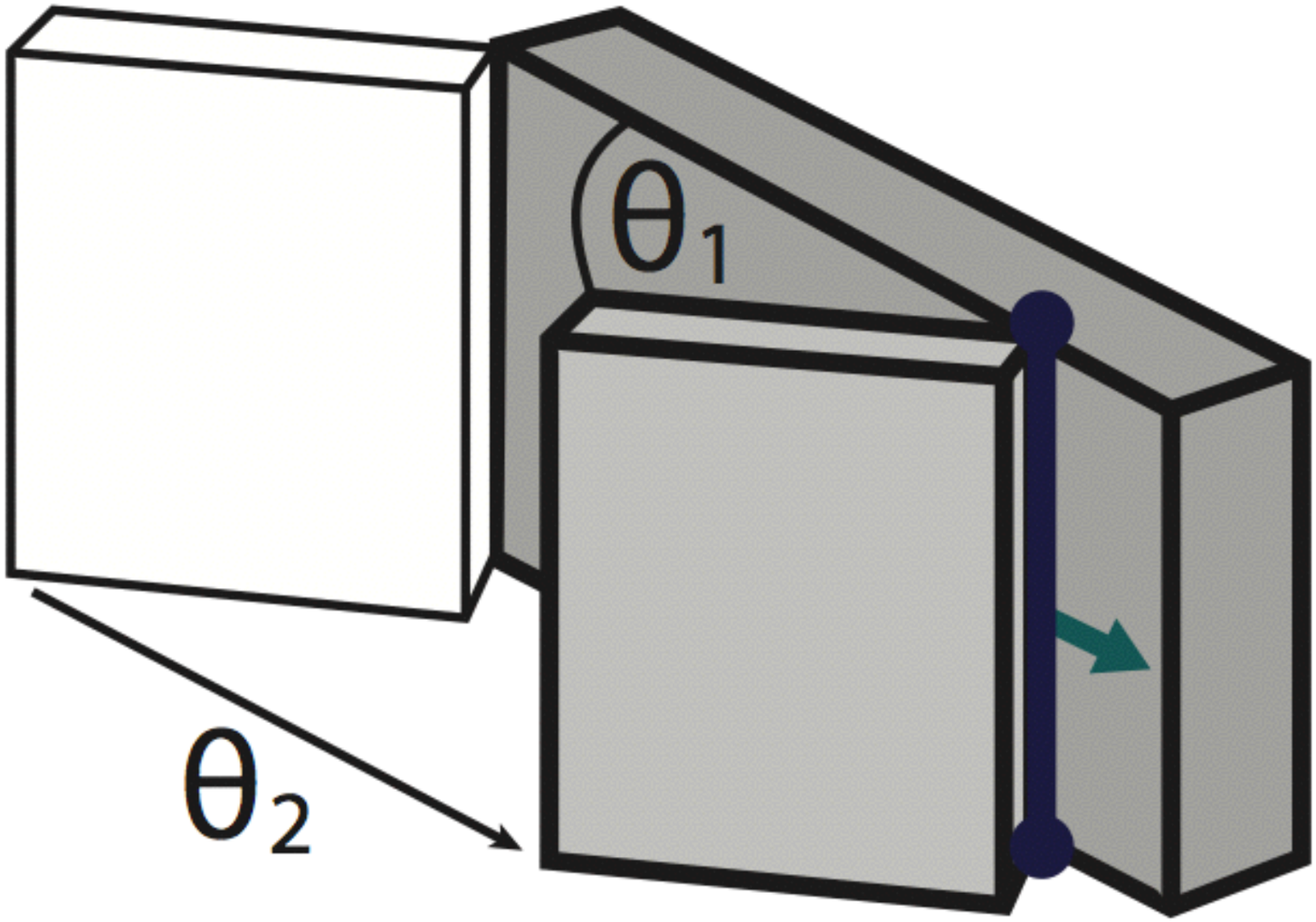
2. Sliding joint

→ sliding vector



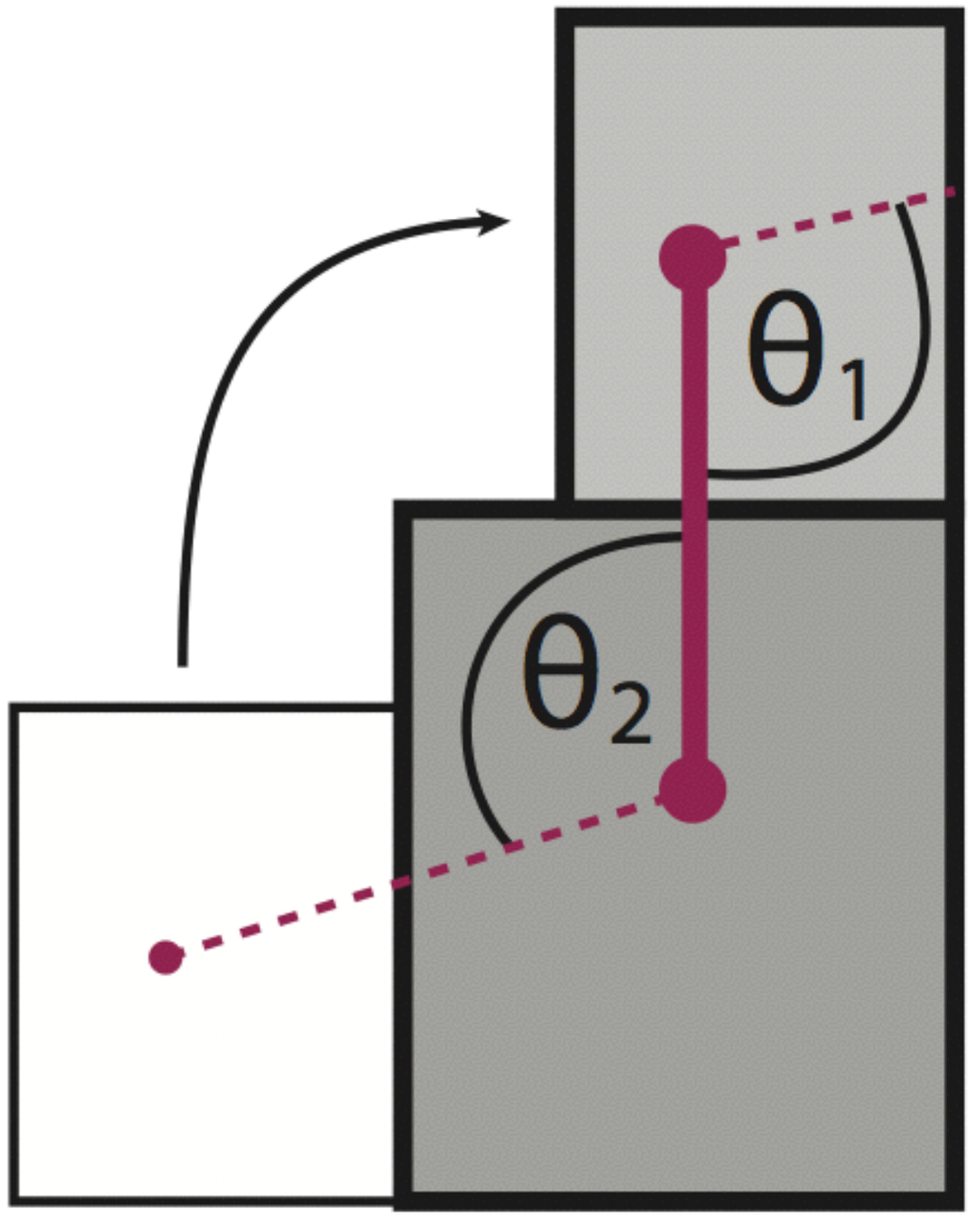
3. Sliding hinge

rotation axis → sliding vector



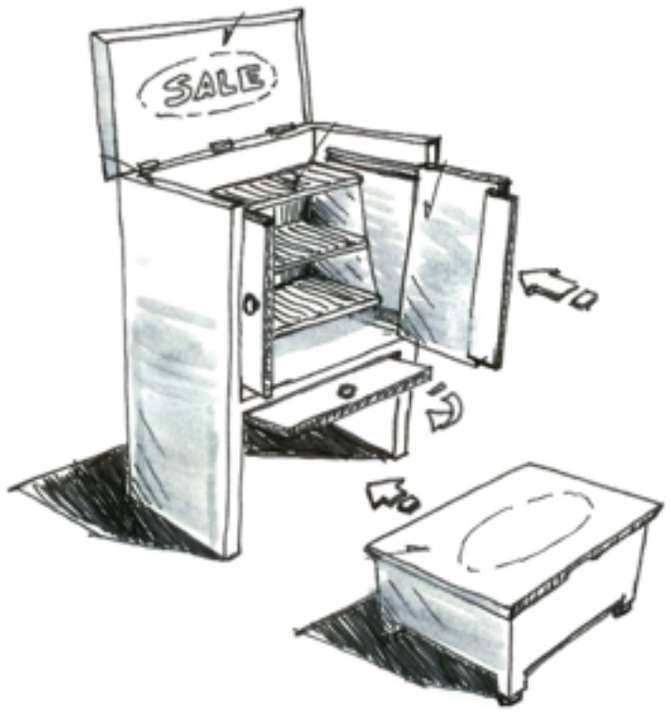
4. Double pivot

double pivot



Overview

Input



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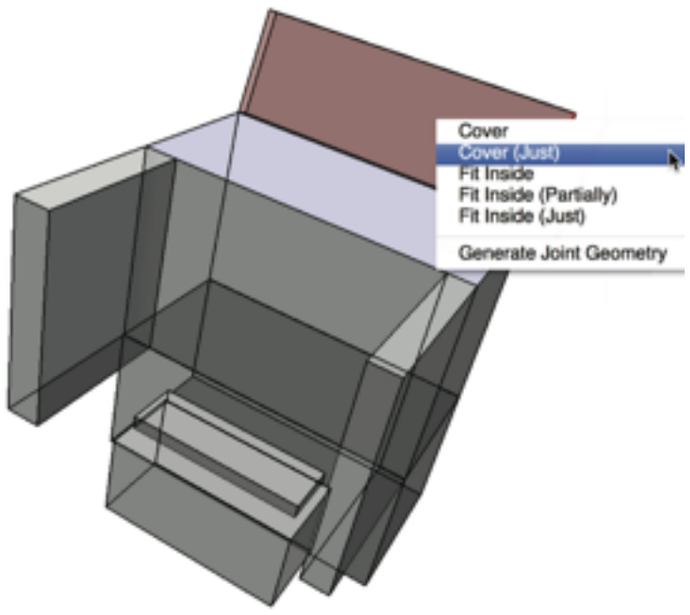


Functional relationships

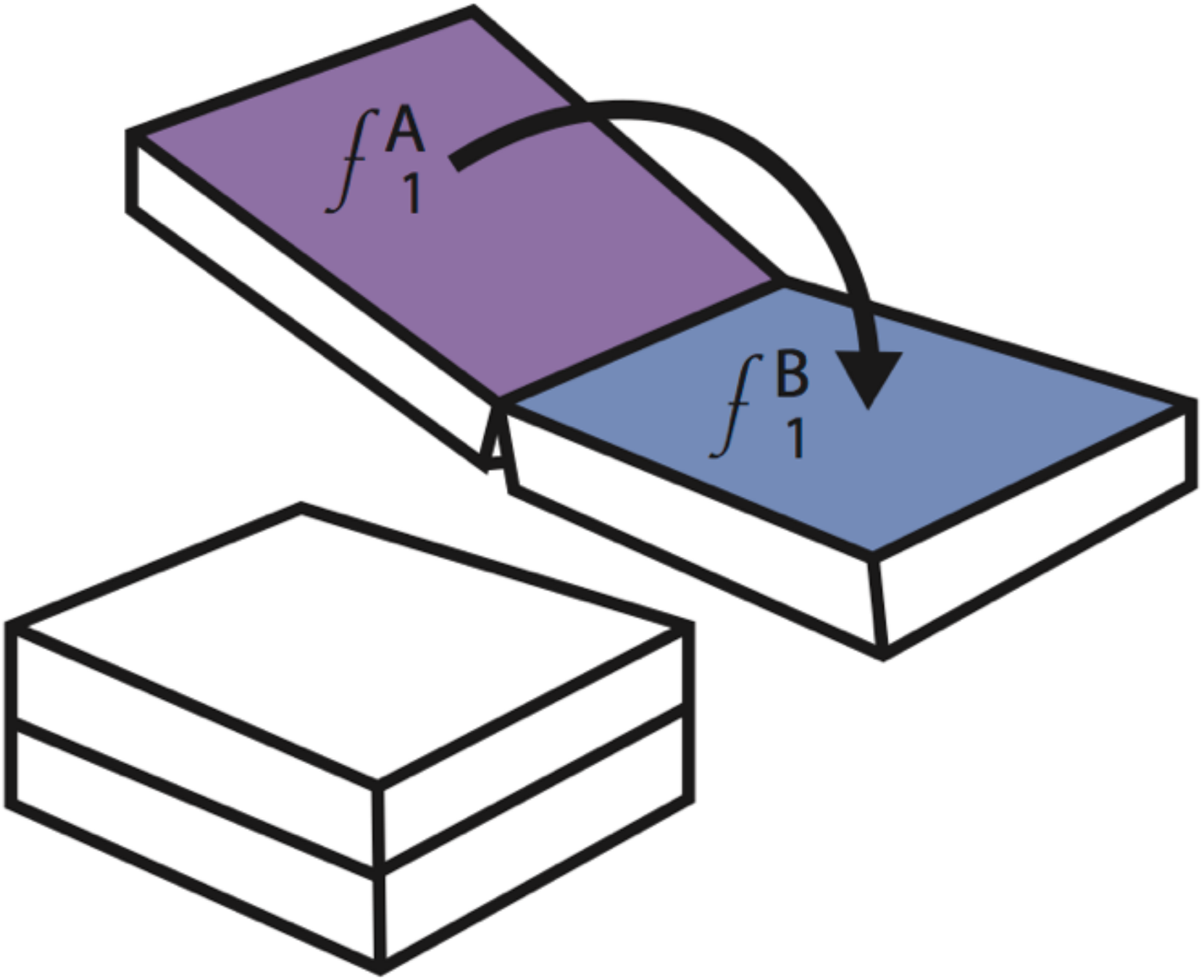
Functional Relationships

Functional relationships

Functional Relationships

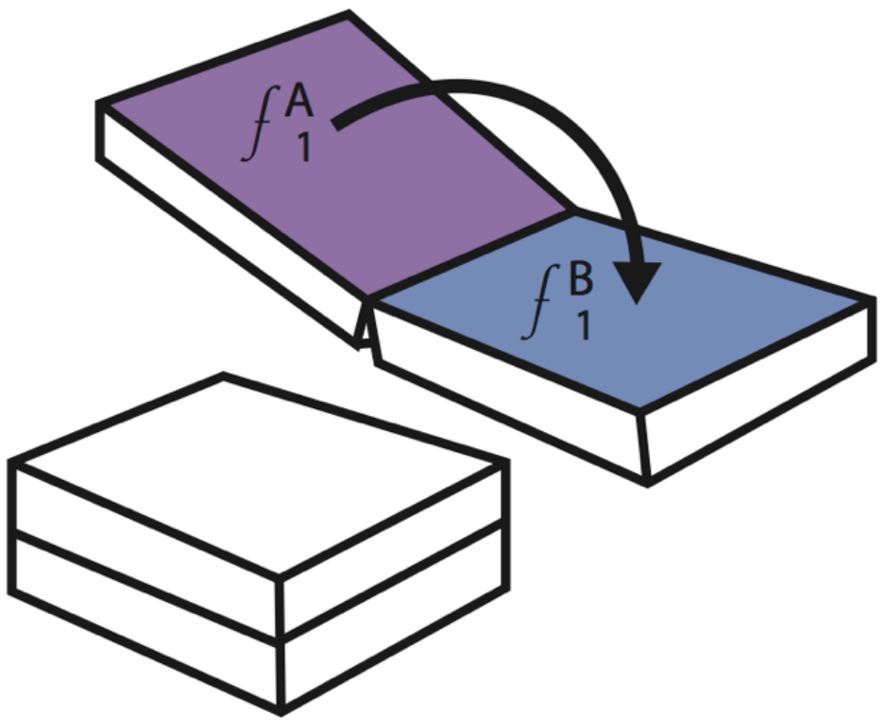
1. Cover

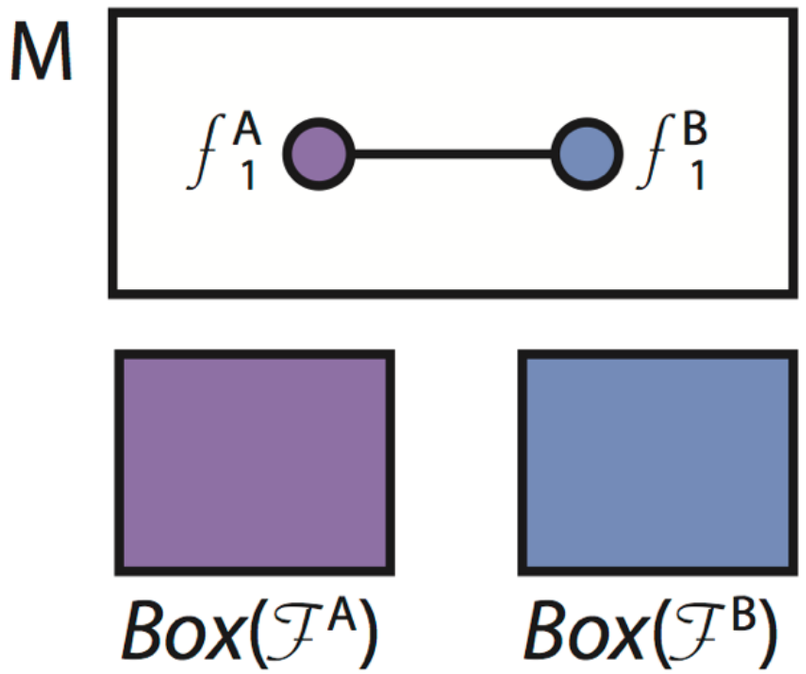
covering face covered face



1. Cover

covering face covered face





$Cover(F^A, F^B, M, J, \Theta)$

F^A covers F^B

M : a corresponding faces graph

$J(\Theta)$: the set of joints and parameters

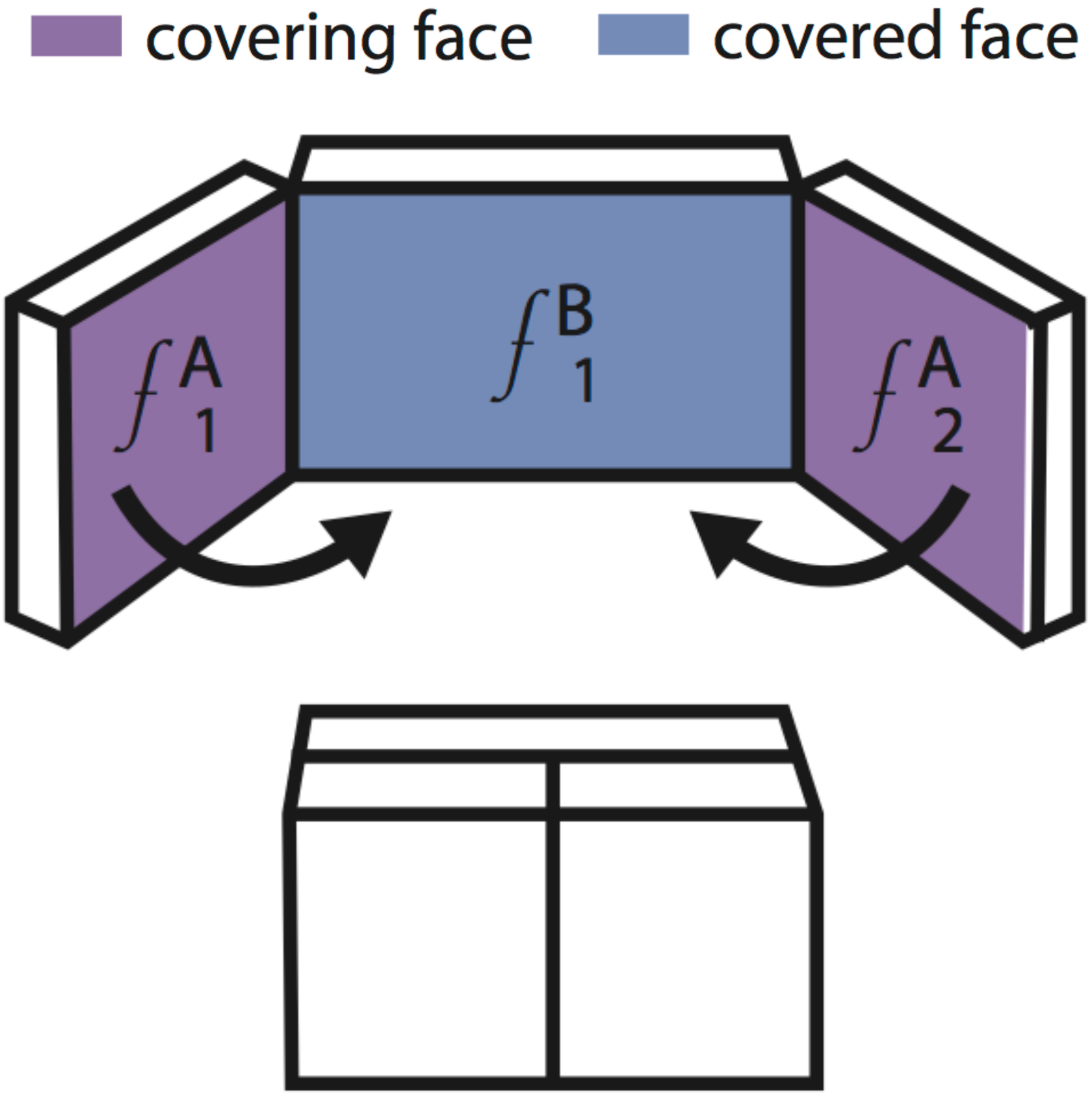
$$Box(F^A)_l \leq Box(F^B)_l$$

$$Box(F^A)_r \geq Box(F^B)_r$$

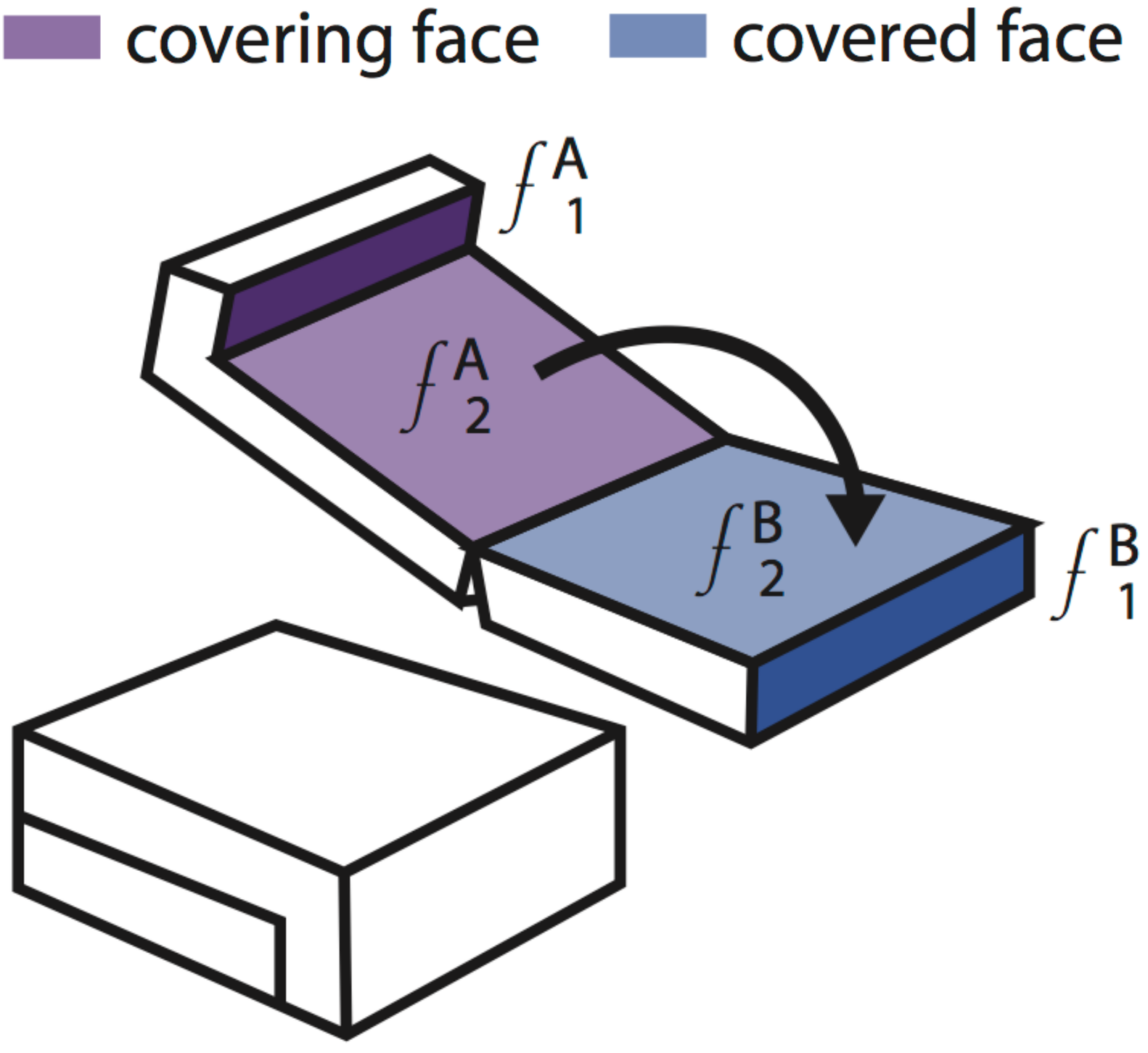
$$Box(F^A)_b \leq Box(F^B)_b$$

$$Box(F^A)_t \geq Box(F^B)_t$$

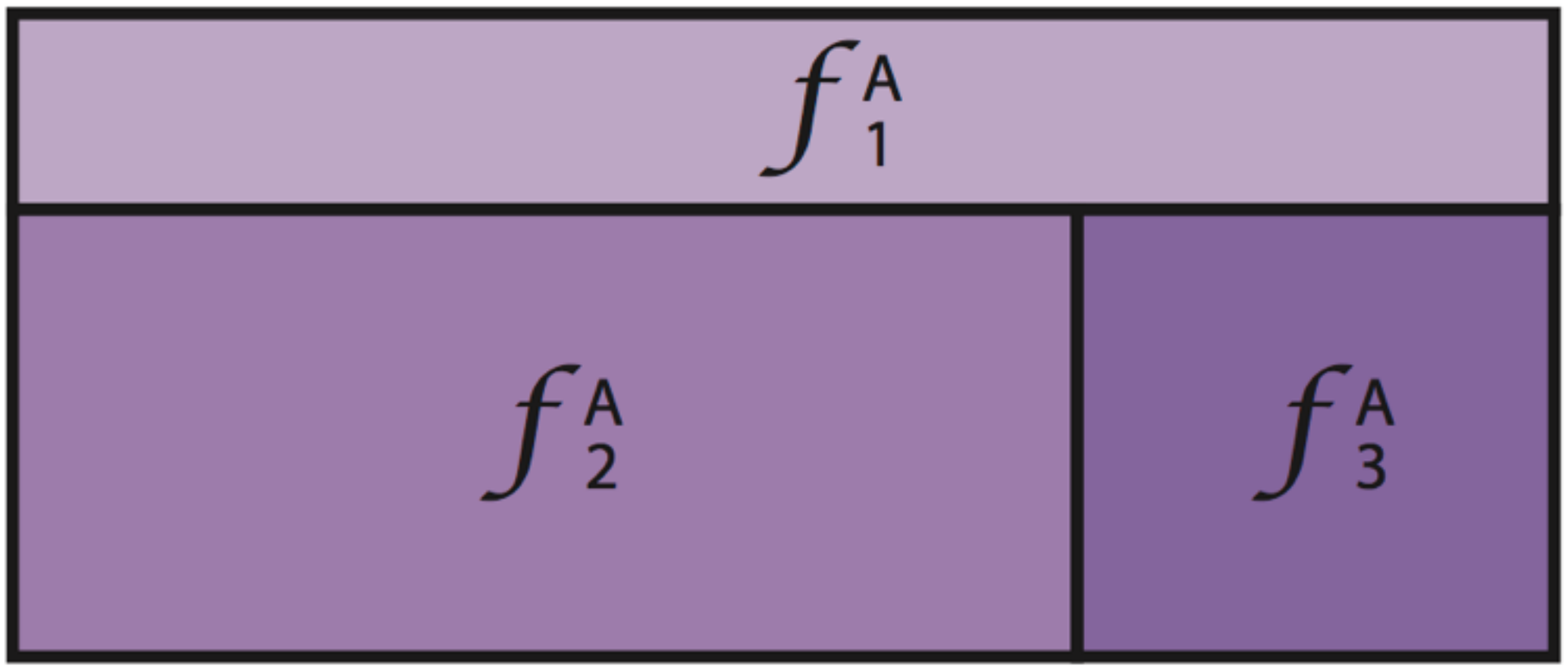
1. Cover



1. Cover



1. Cover

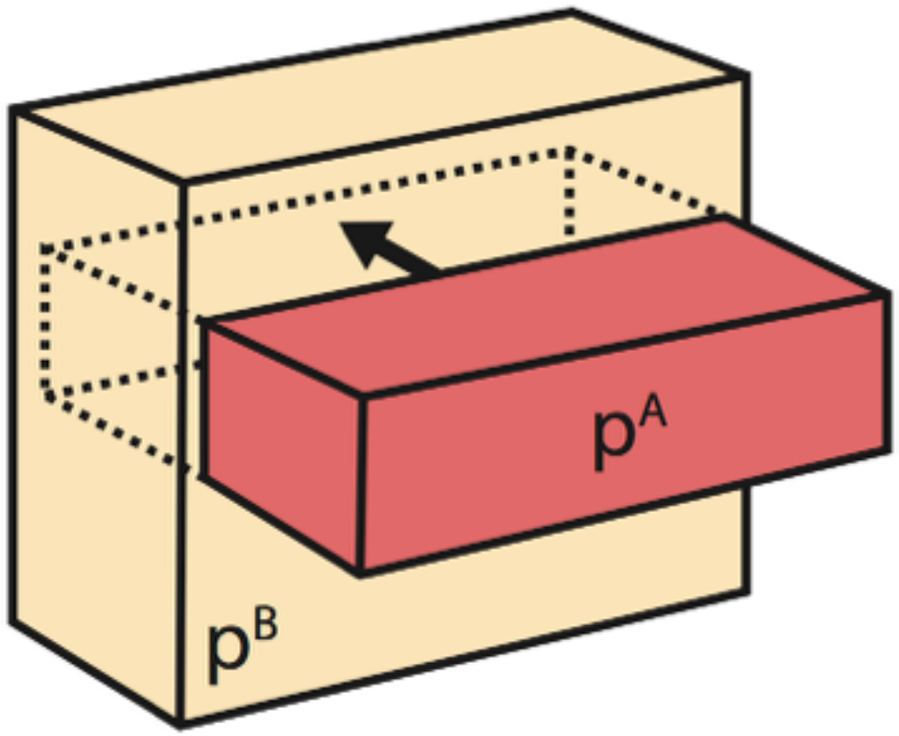


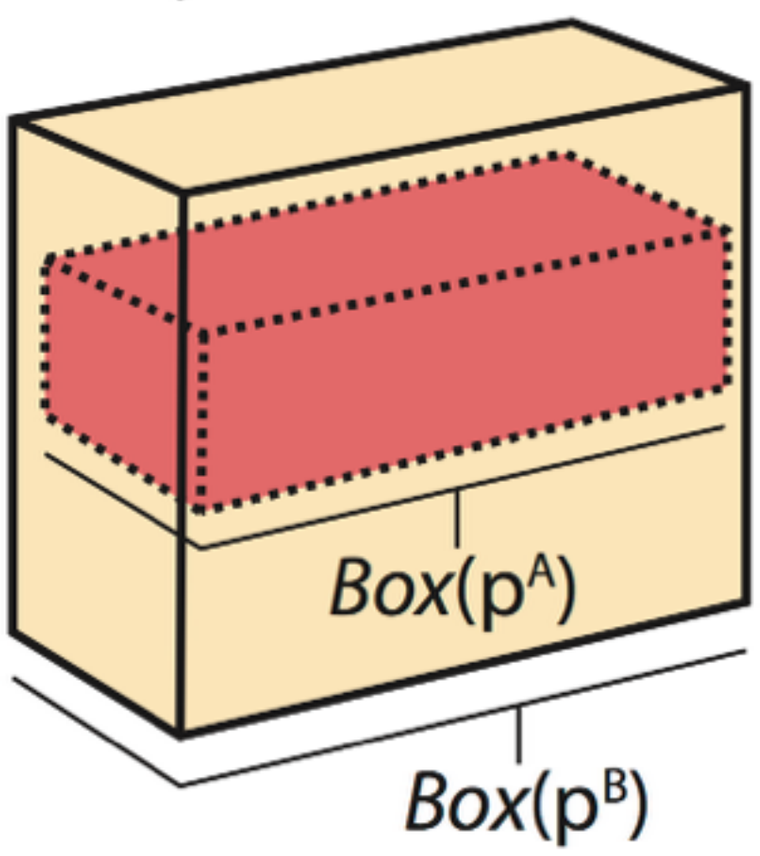
$$Box(f_1^A)_b = Box(f_2^A)_t$$

$$Box(f_1^A)_b = Box(f_3^A)_t$$

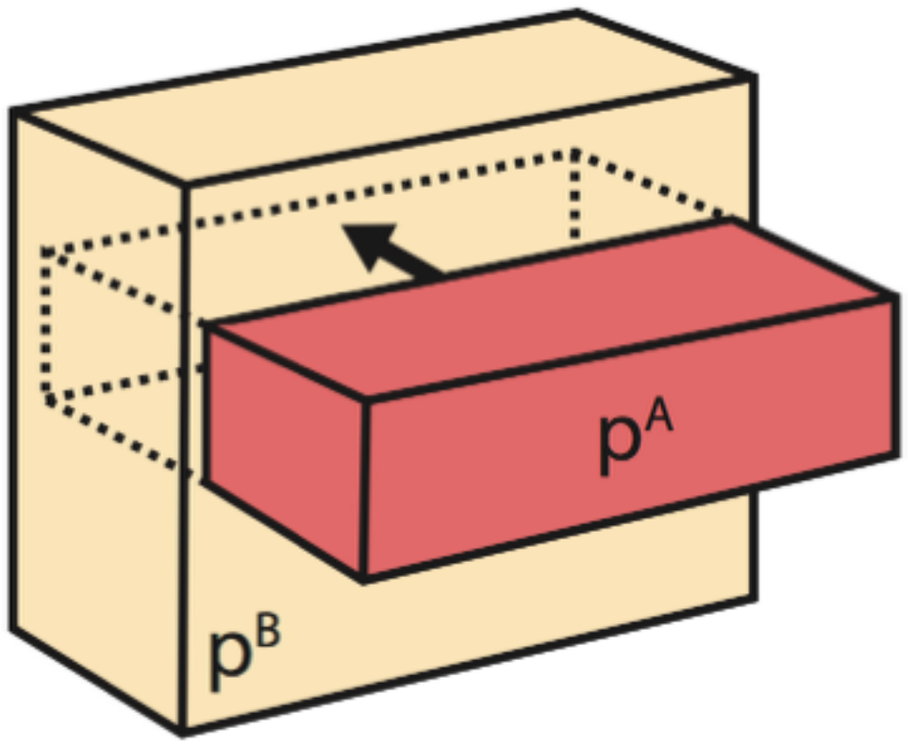
$$Box(f_2^A)_r = Box(f_3^A)_l$$

2. Fit inside





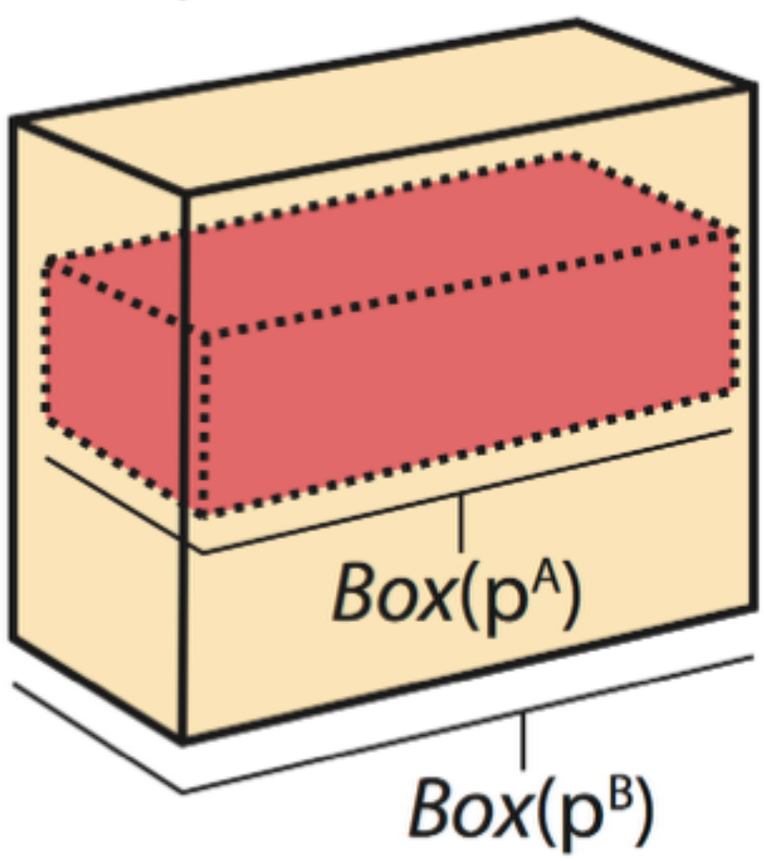
2. Fit inside



$$Fit(P^A, p^B, J, \Theta)$$

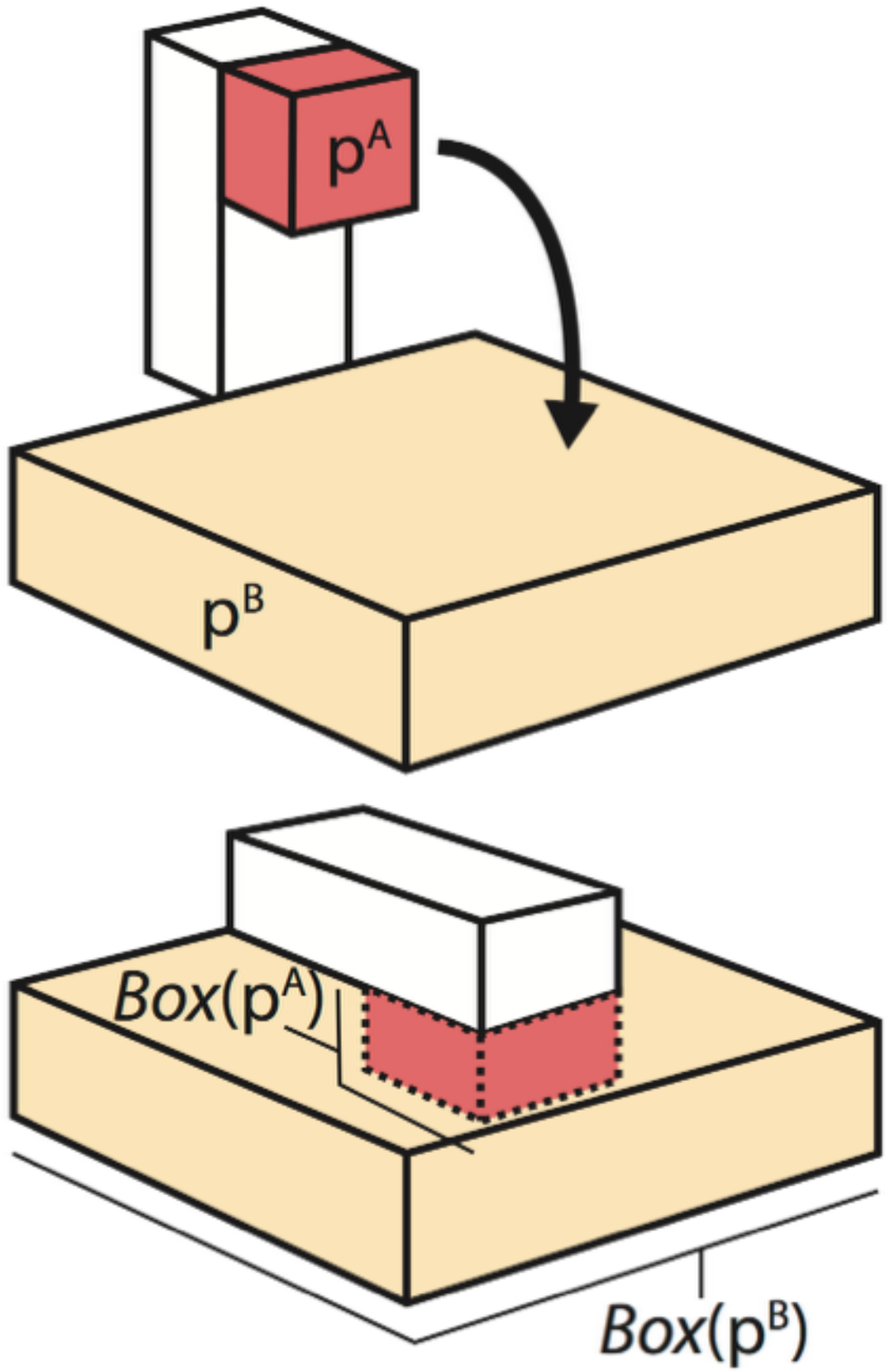
P^A fit inside p^B

$J(\Theta)$: the set of joints and parameters

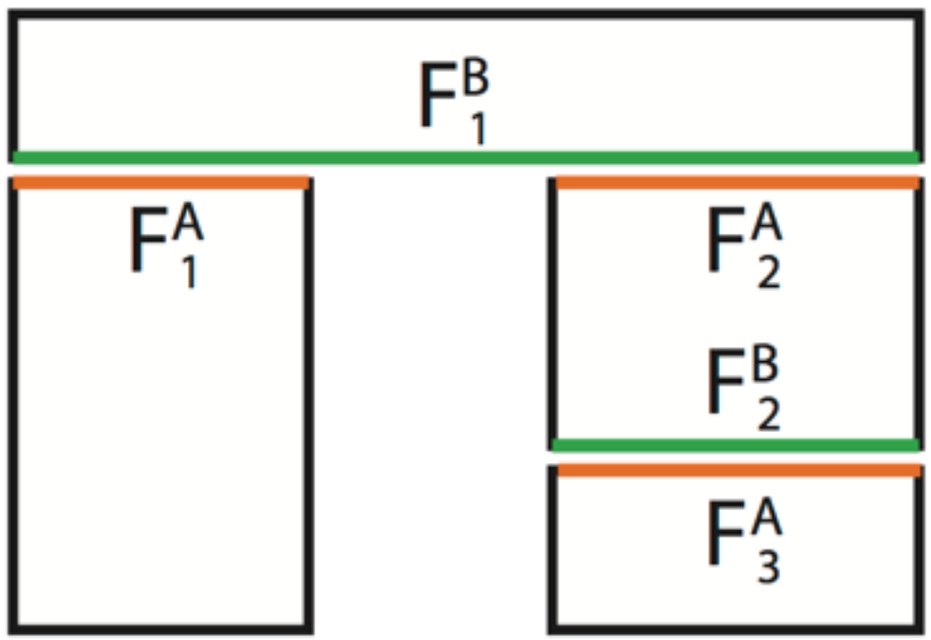


$$Box(P^A)_l \geq Box(p^B)_l \quad Box(P^A)_r \leq Box(p^B)_r$$
$$Box(P^A)_b \geq Box(p^B)_b \quad Box(P^A)_t \leq Box(p^B)_t$$
$$Box(P^A)_n \geq Box(p^B)_n \quad Box(P^A)_f \leq Box(p^B)_f$$

2. Fit inside



3. Support



$Support(F^A, F^B, M, J, \Theta)$

F^A, F^B : the set of supporting / supported faces

M : a corresponding faces graph

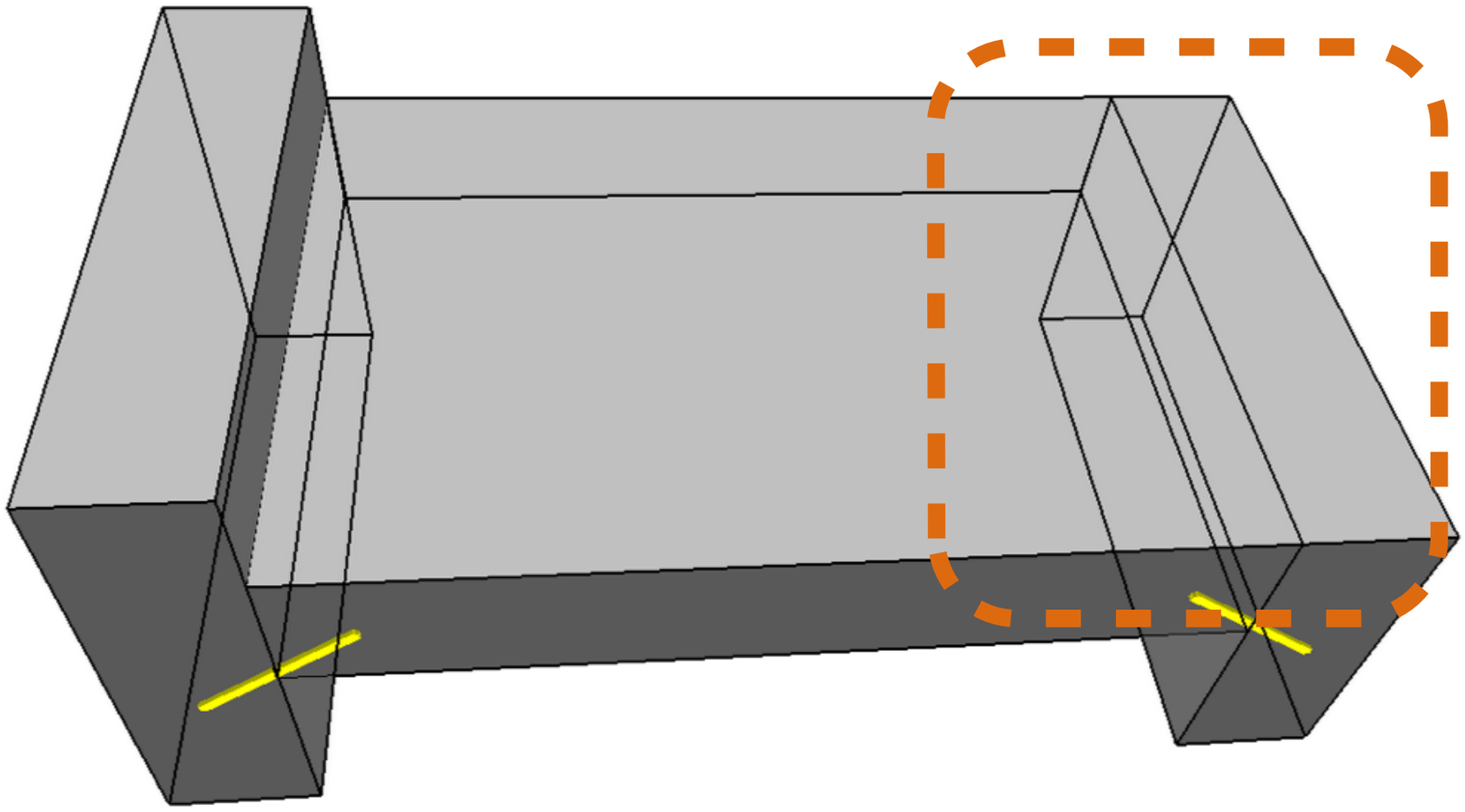
$J(\Theta)$: the set of joints and parameters

$$f_l^A < f_r^B \qquad f_t^A < f_b^B$$

$$f_r^A > f_l^B \qquad f_b^A > f_t^B$$

$$c_t^A = c_b^B$$

4. Flush

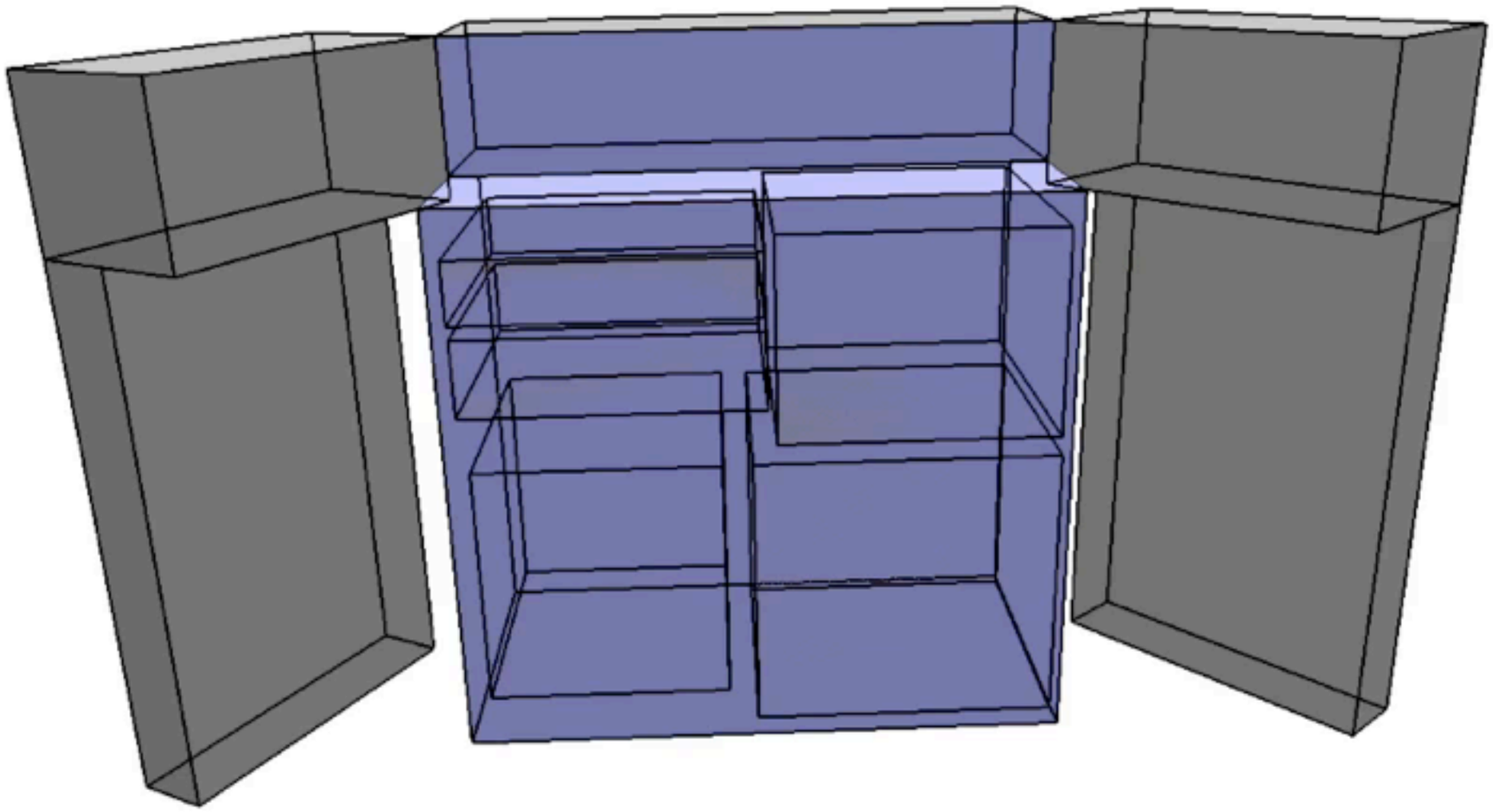


$Flush(f^A, f^B, J, \Theta)$

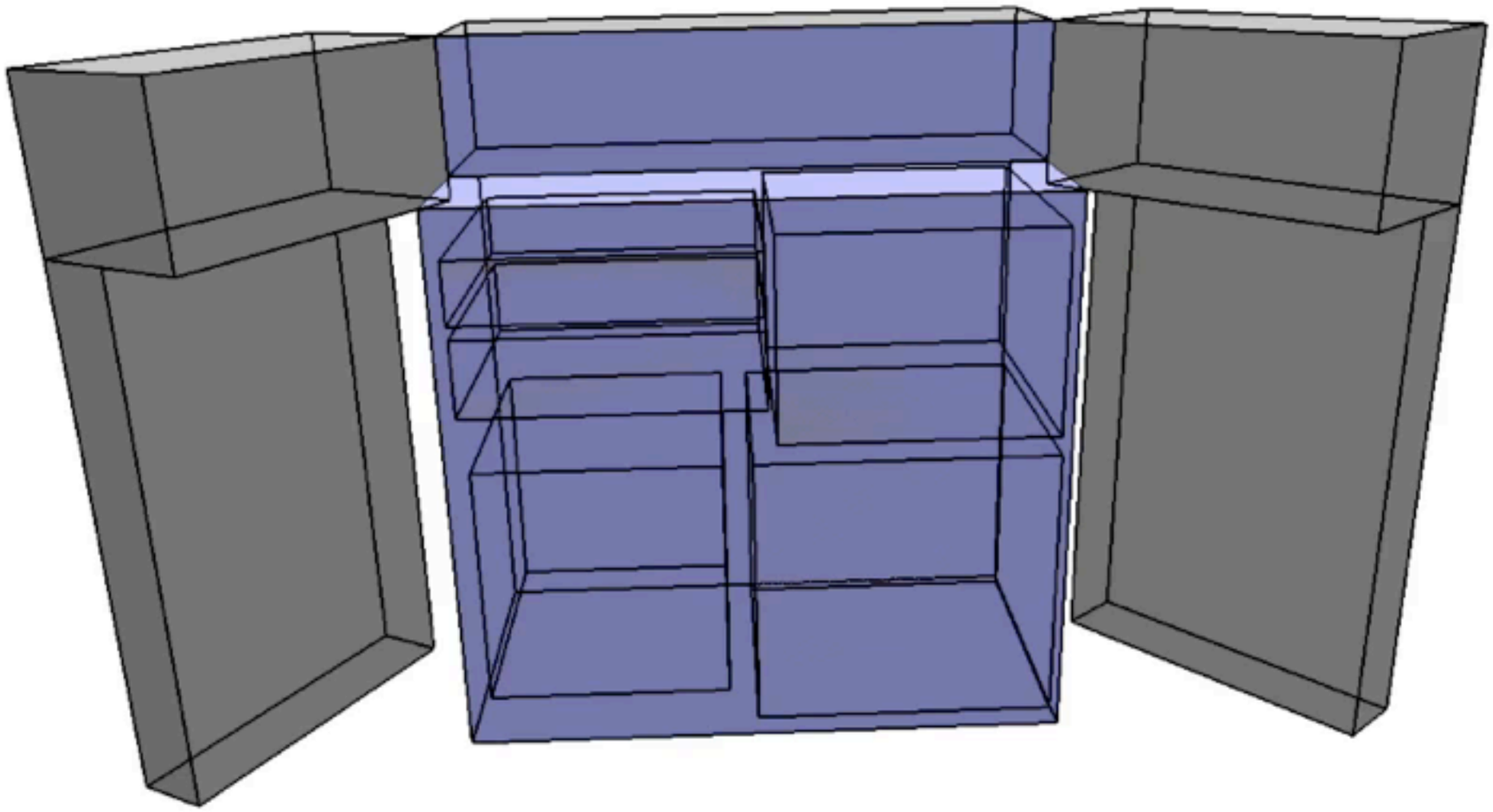
f^A, f^B : the two faces that are flush

$J(\Theta)$: the set of joints and parameters

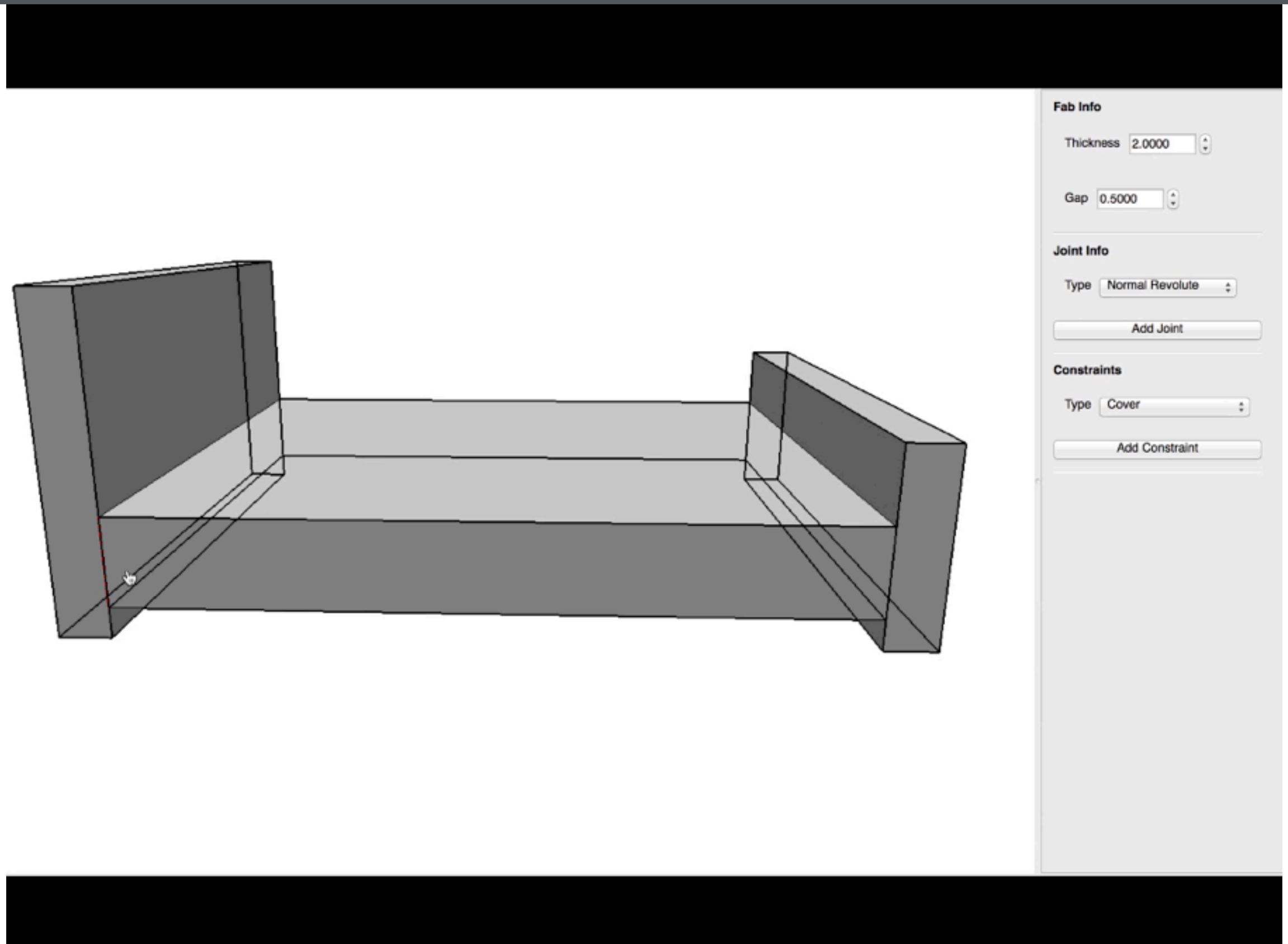
Specifying functional relationships



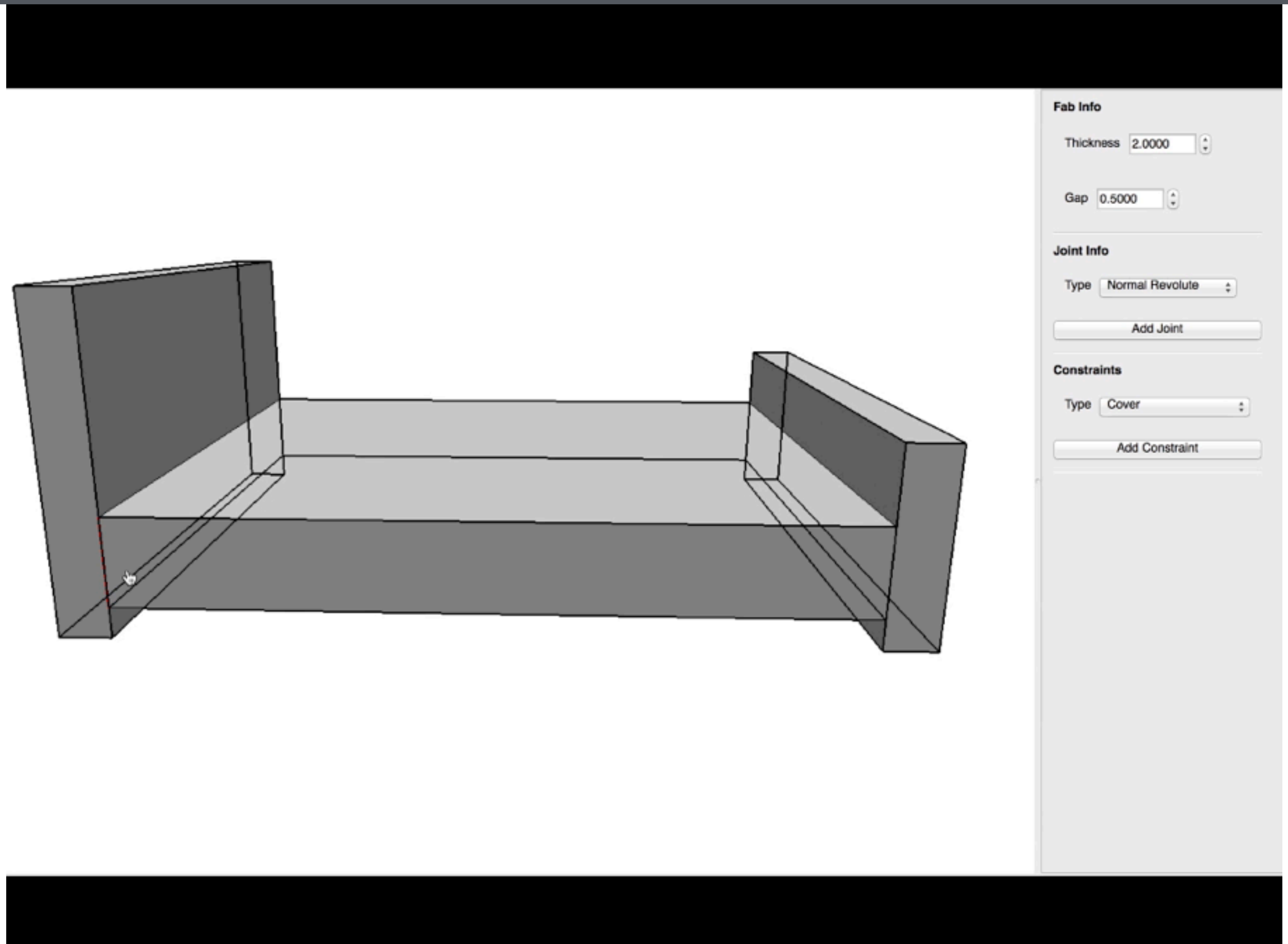
Specifying functional relationships



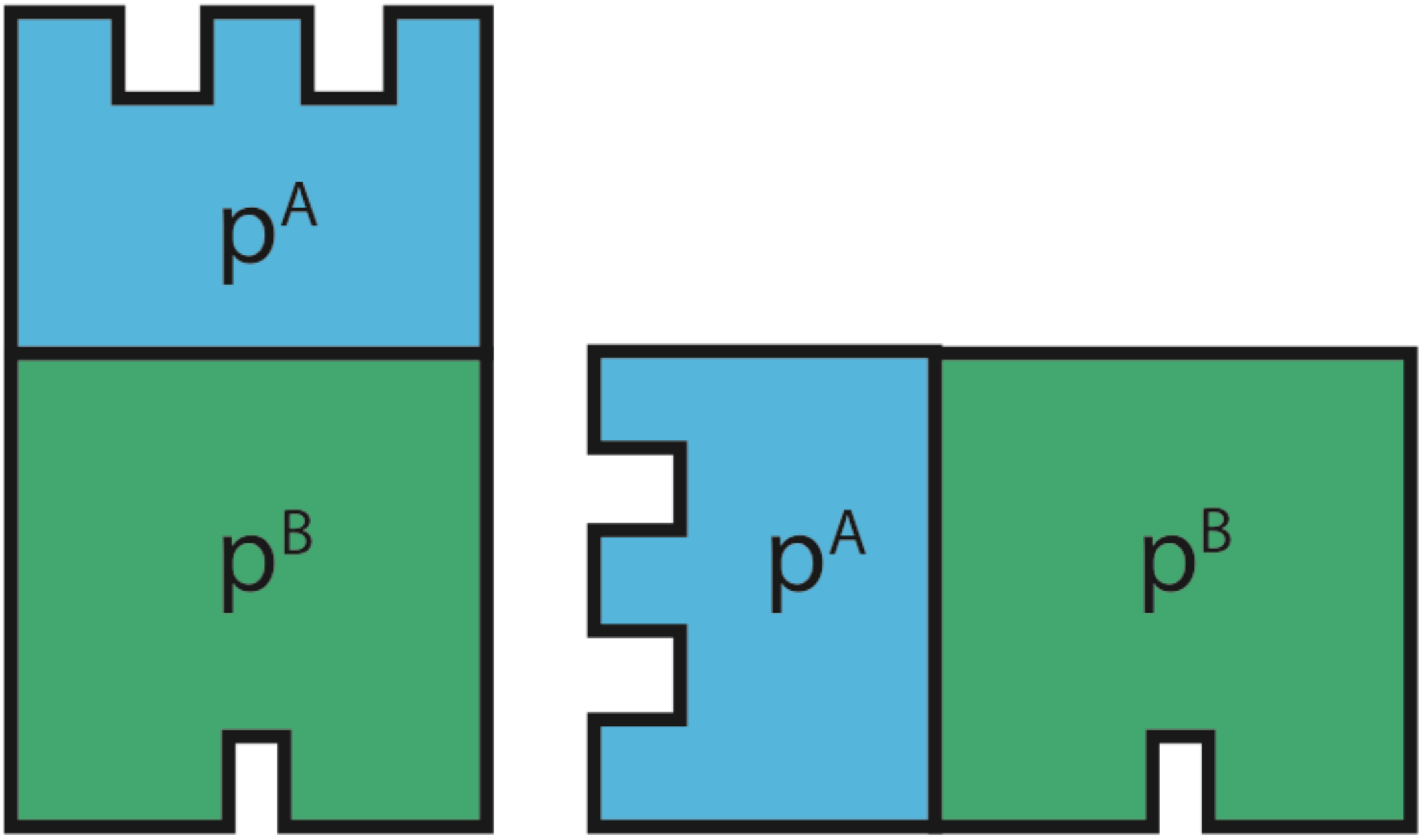
Double pivot joints go wrong



Double pivot joints go wrong

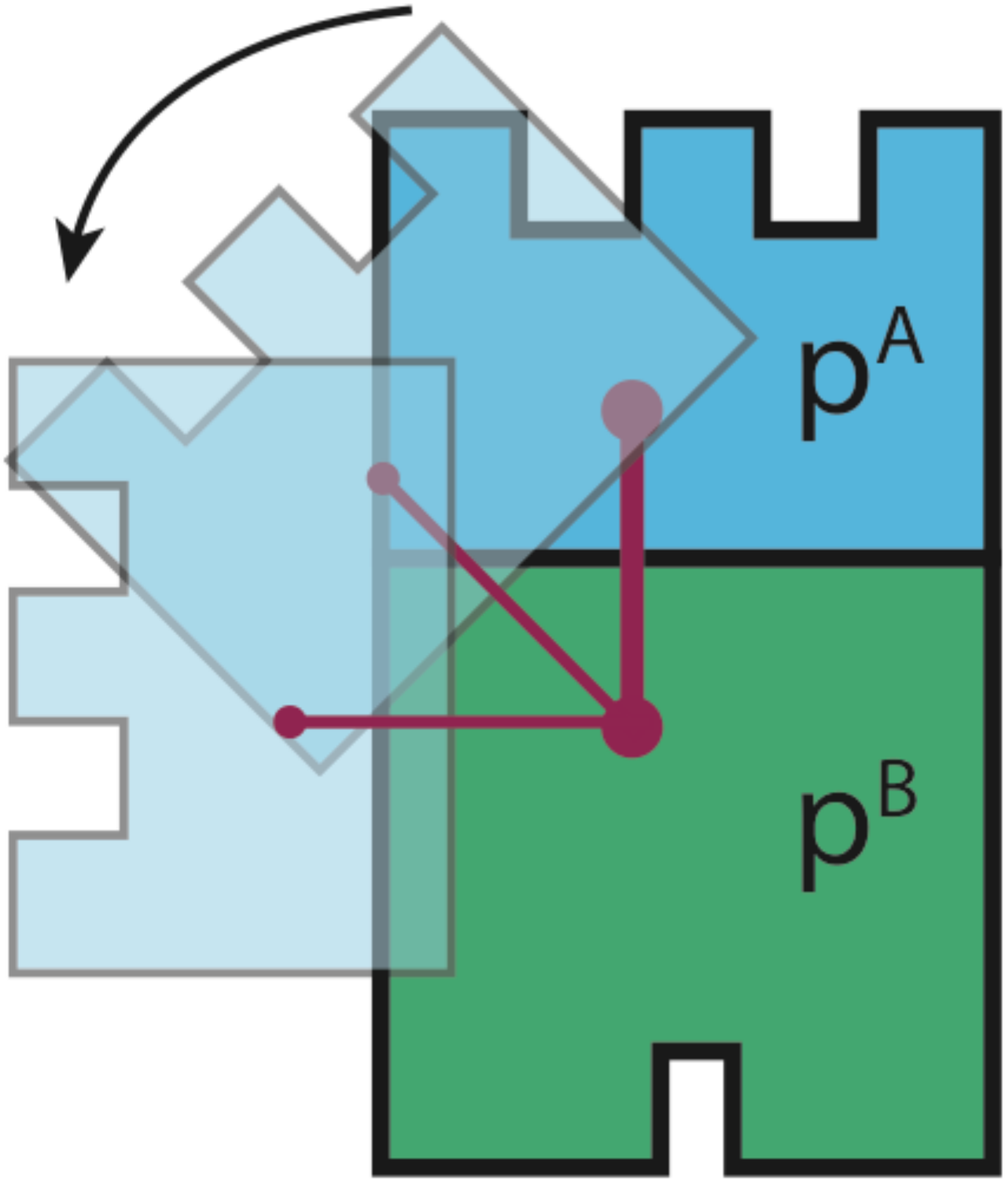


Double pivot joint constraints

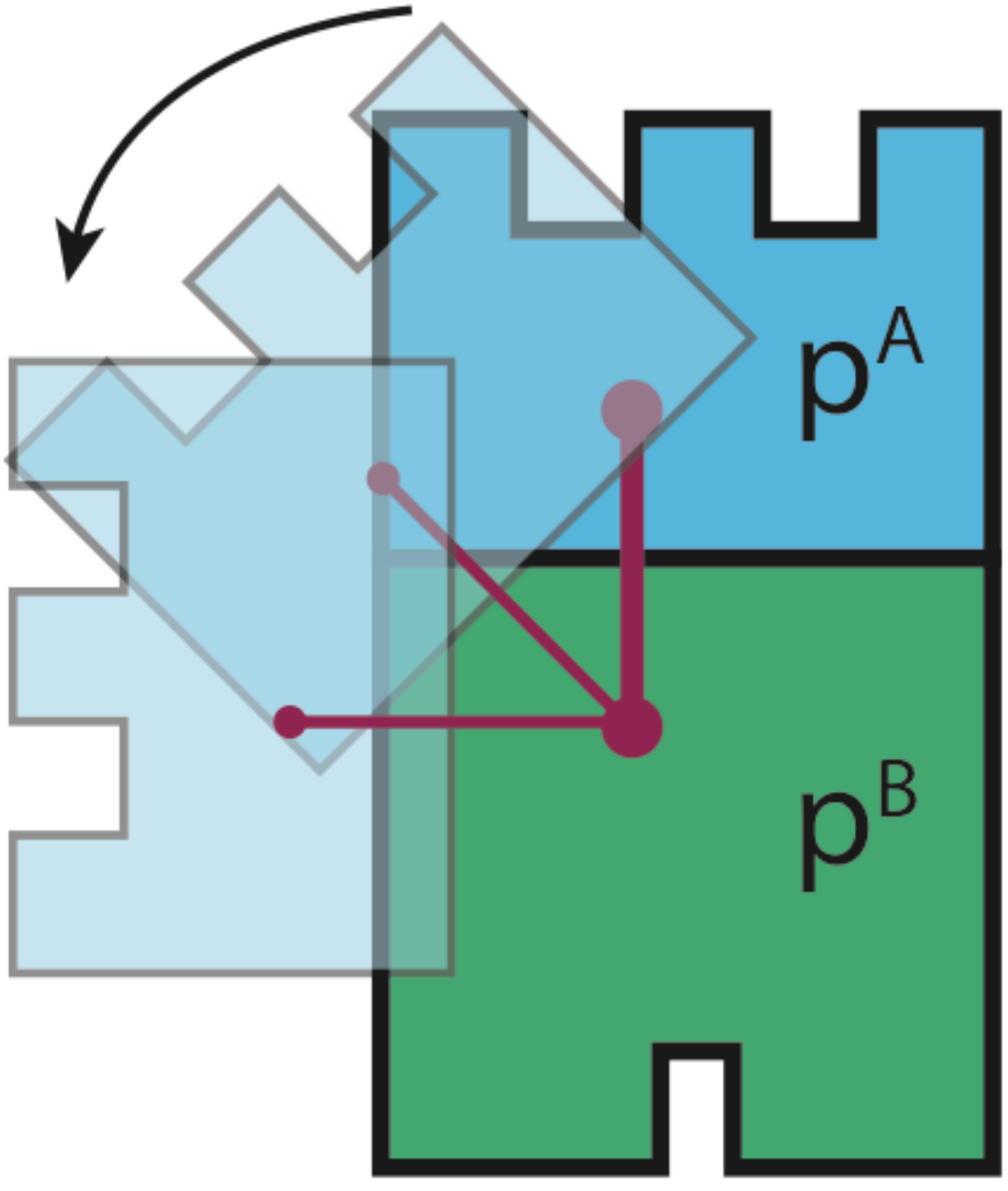


(a) C_1 (b) C_2

Double pivot joint constraints



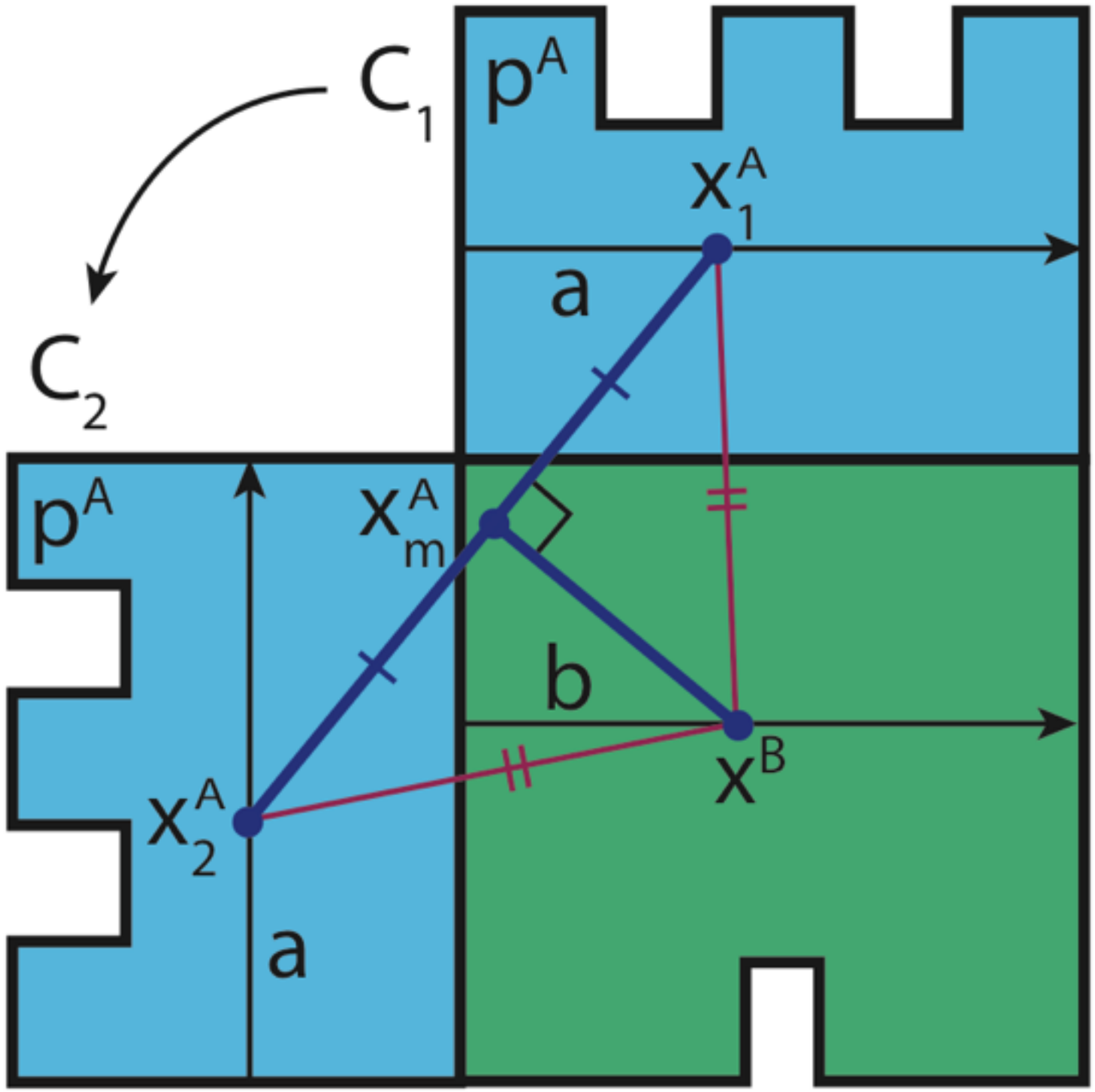
Double pivot joint constraints



Position constraint

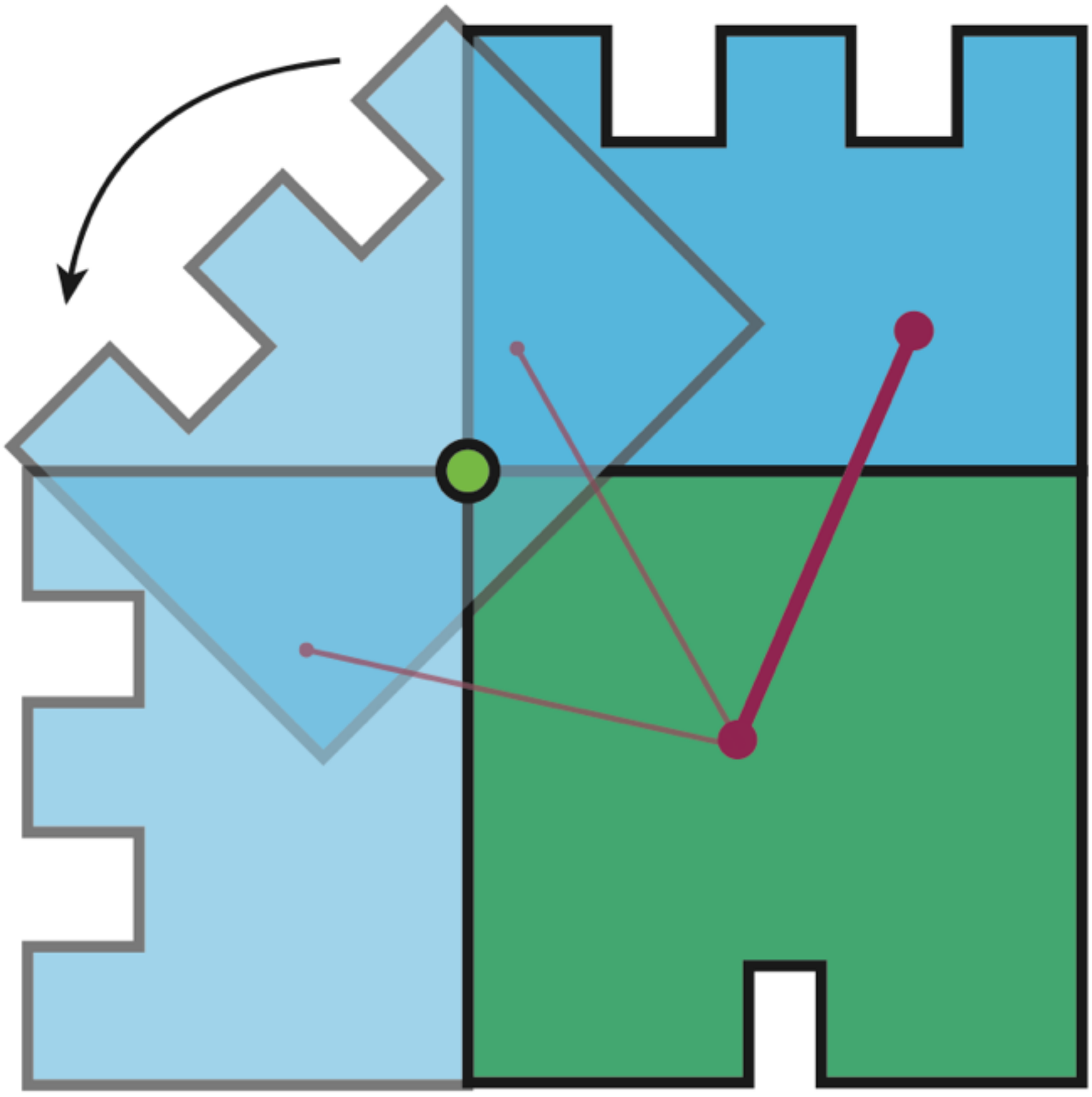
Motion constraint

1. Position constraint

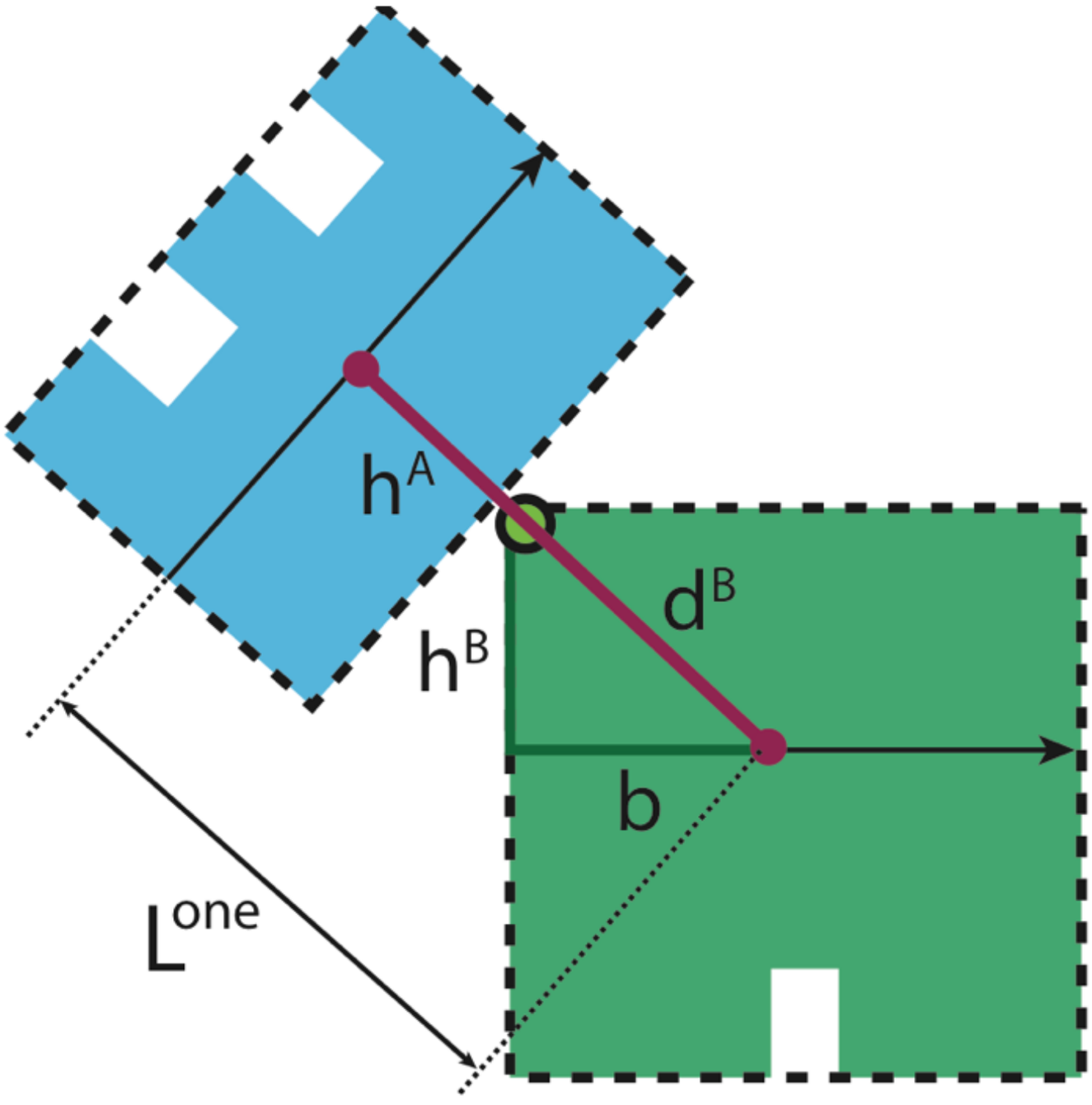


$$(x_2^A - x_1^A) \cdot (x_m^A - x^B) = 0$$

2. Motion constraint



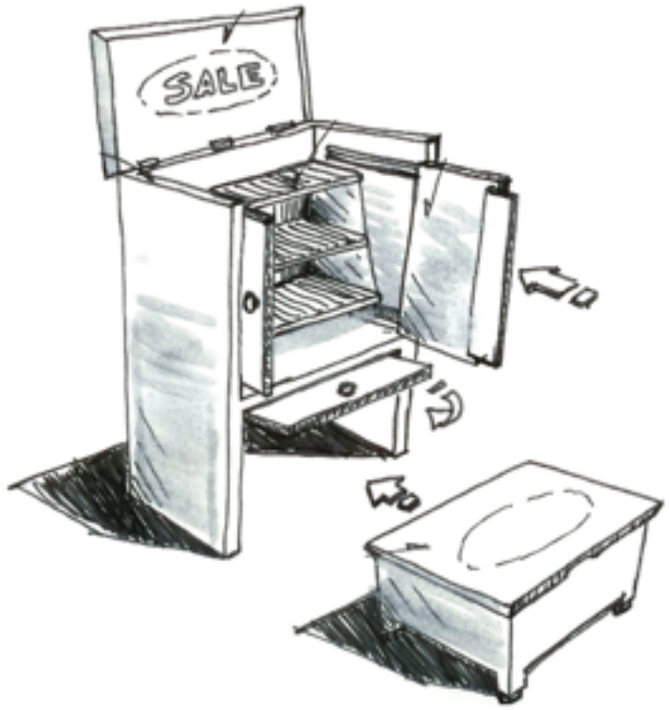
2. Motion constraint



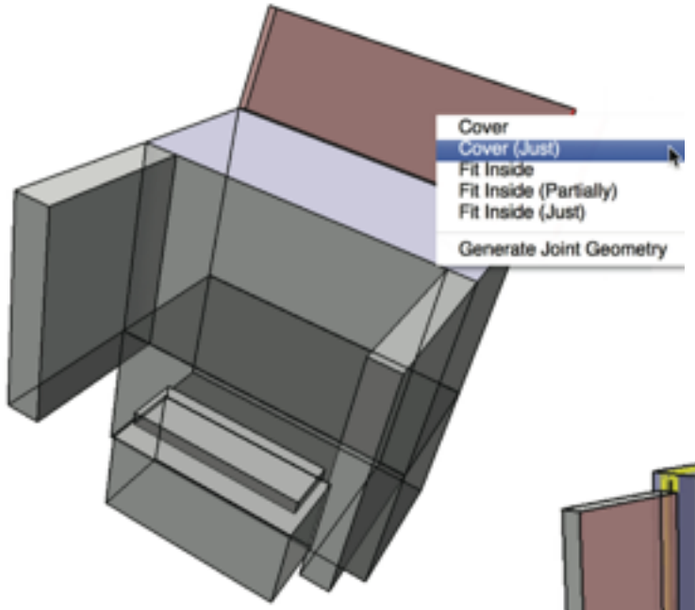
$$L^{one} > h^{A} + (h^{B} + b) / \sqrt{2}$$

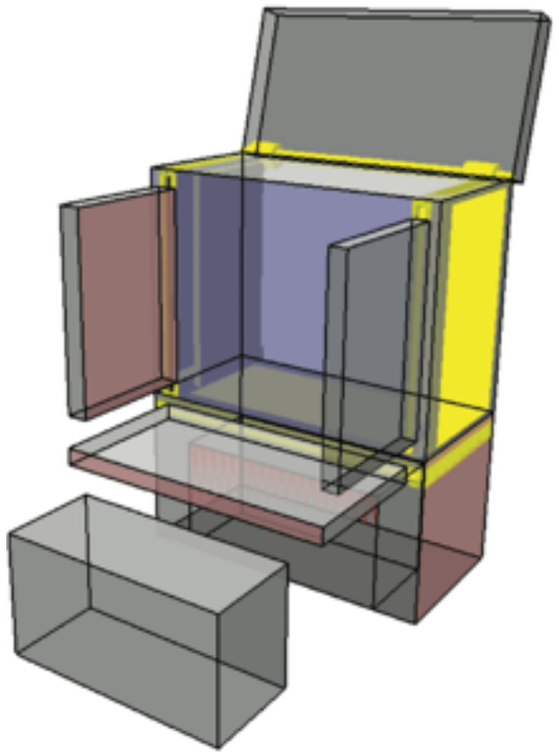
Overview

Input



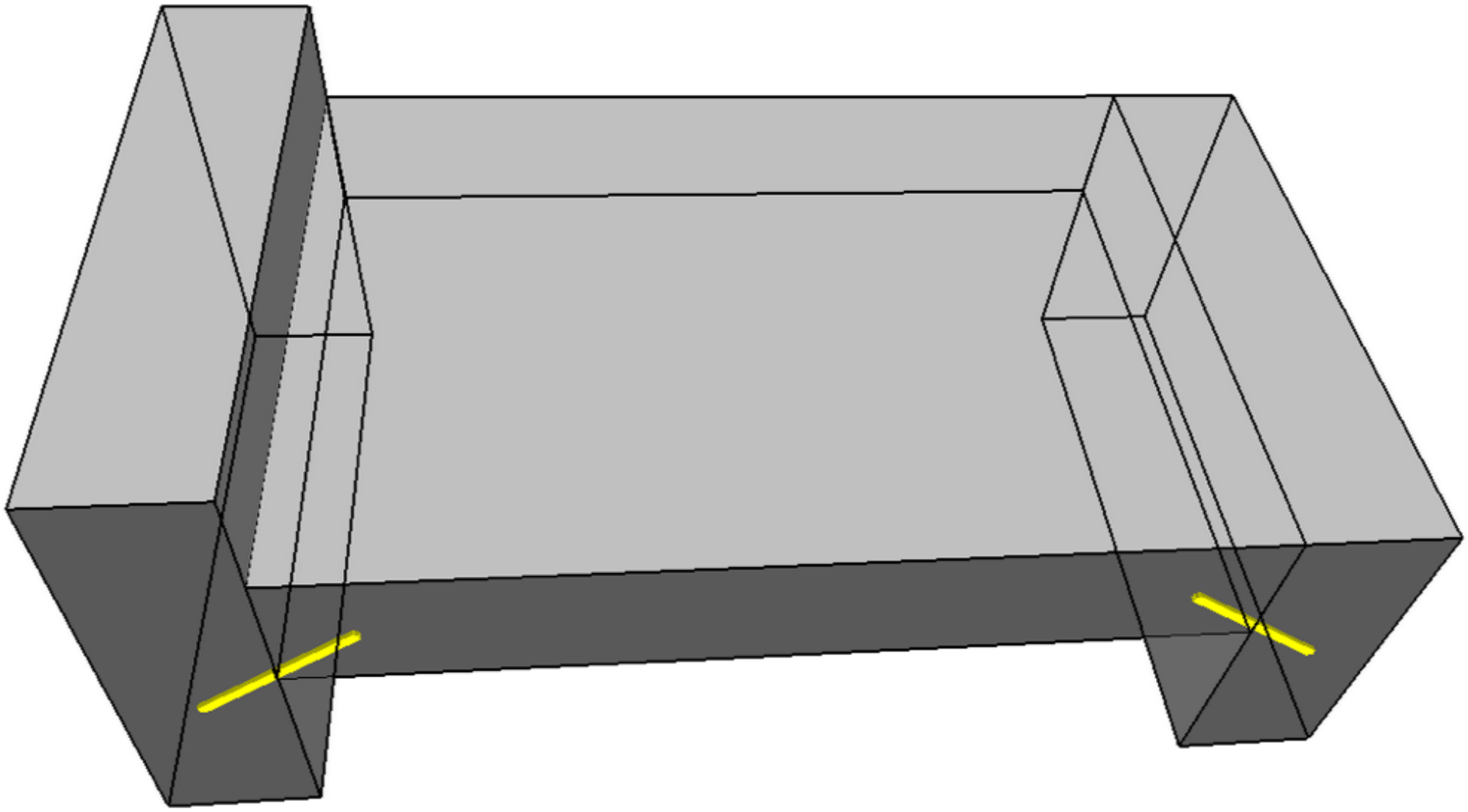
1. Constraints





2. Optimisation

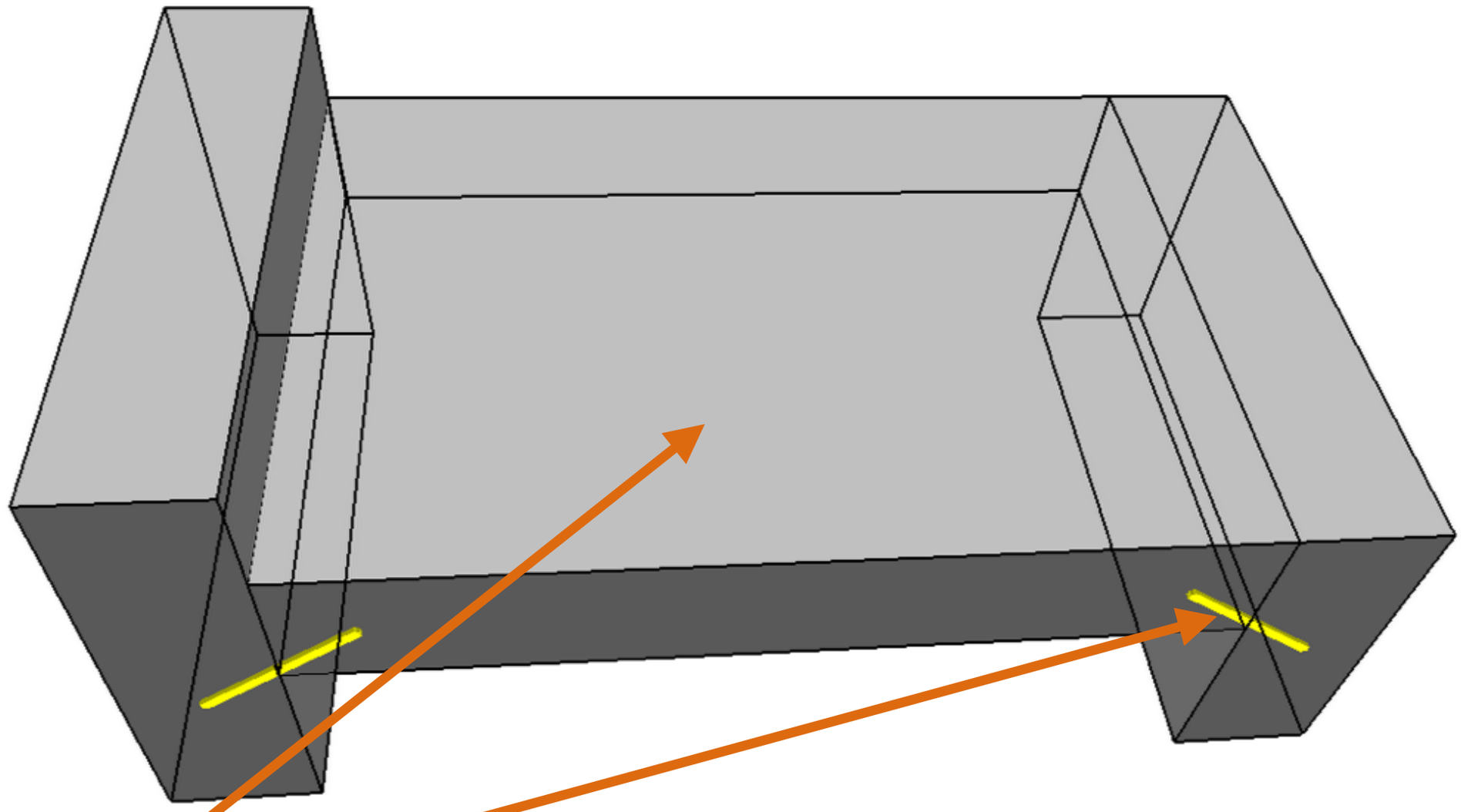
Part and joint optimisation



$$E(B,L)=\sum_i \left\| B_i-\bar{B}_i \right\|^2+\sum_j \left\| L_j-\bar{L}_j \right\|^2$$

subject to functional constraints

Part and joint optimisation

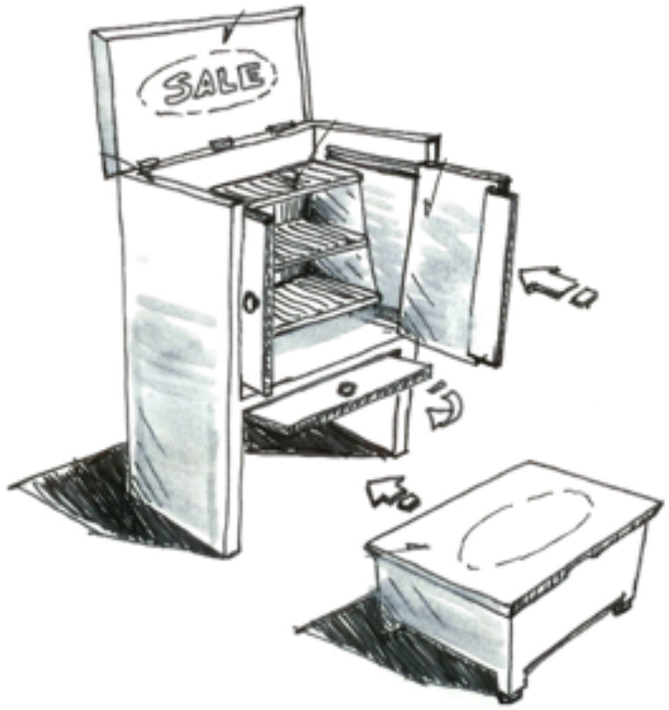


$$E(B,L) = \sum_i \left\| B_i - \bar{B}_i \right\|^2 + \sum_j \left\| L_j - \bar{L}_j \right\|^2$$

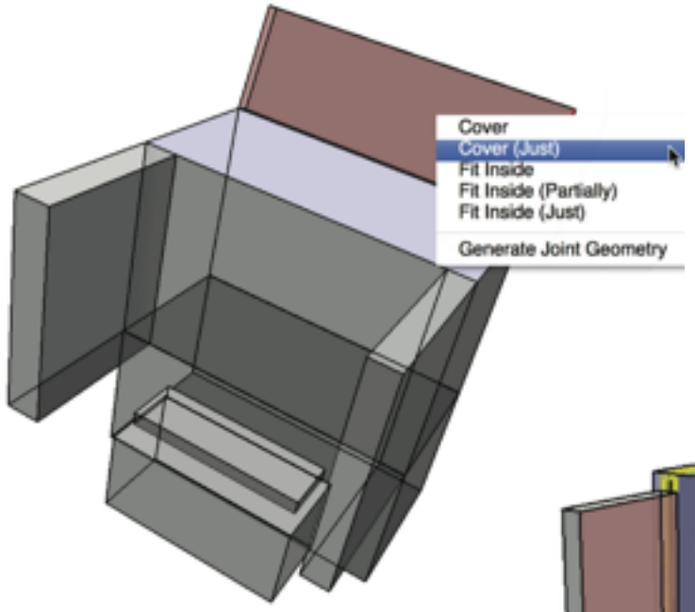
subject to functional constraints

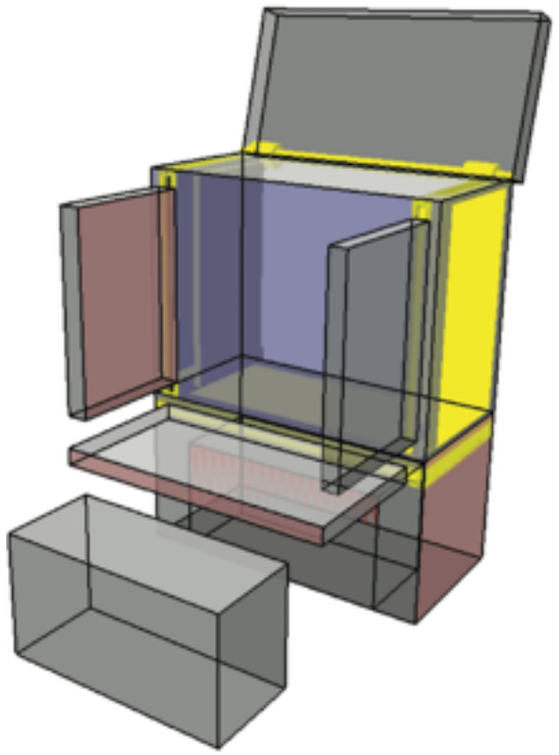
Overview

Input



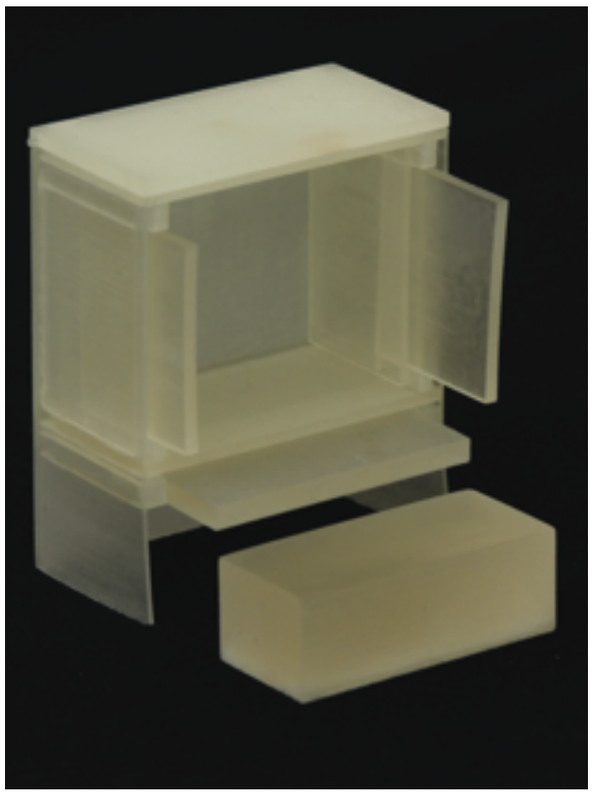
1. Constraints





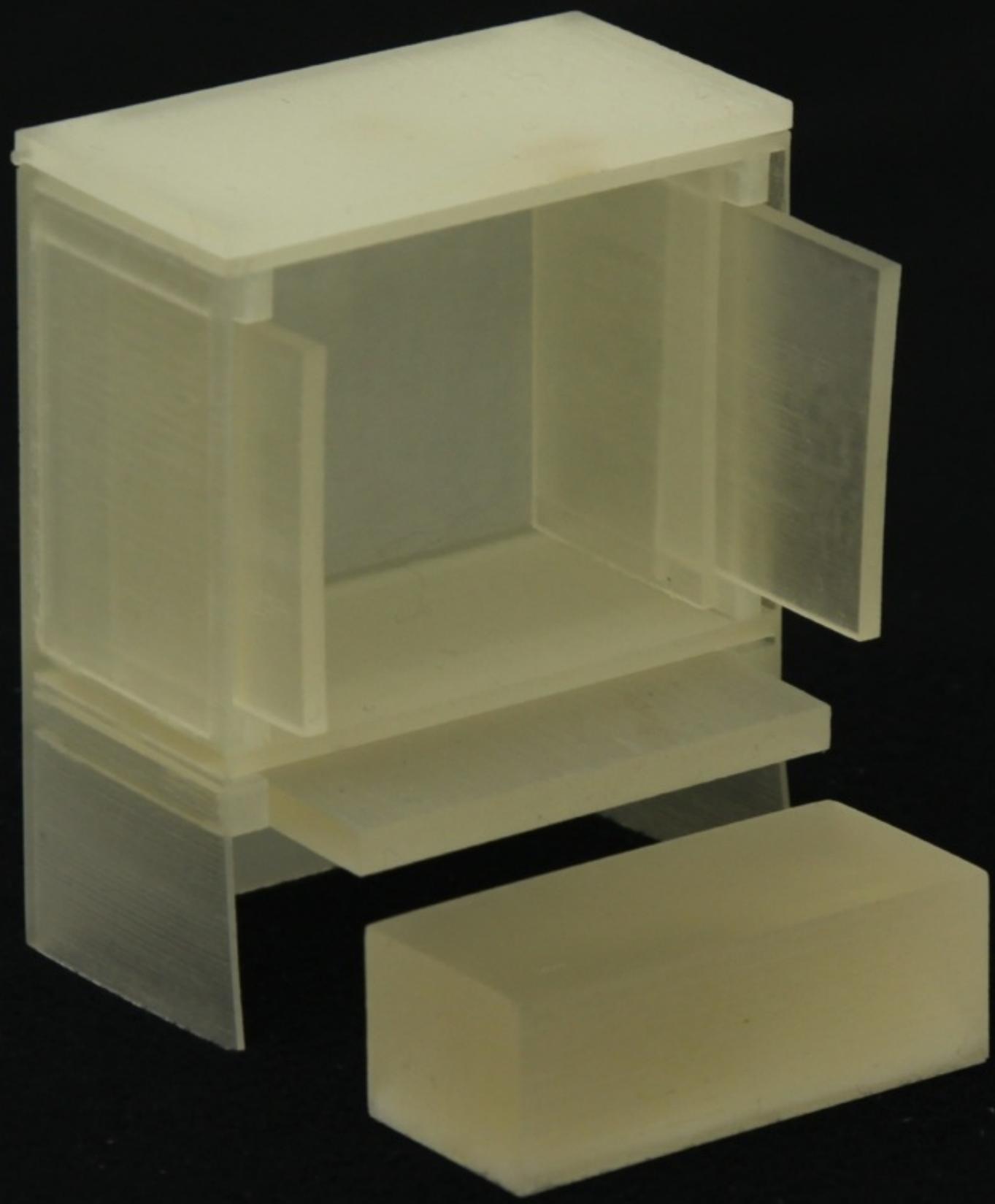
2. Optimisation

Output



Ready-to-fabricate models

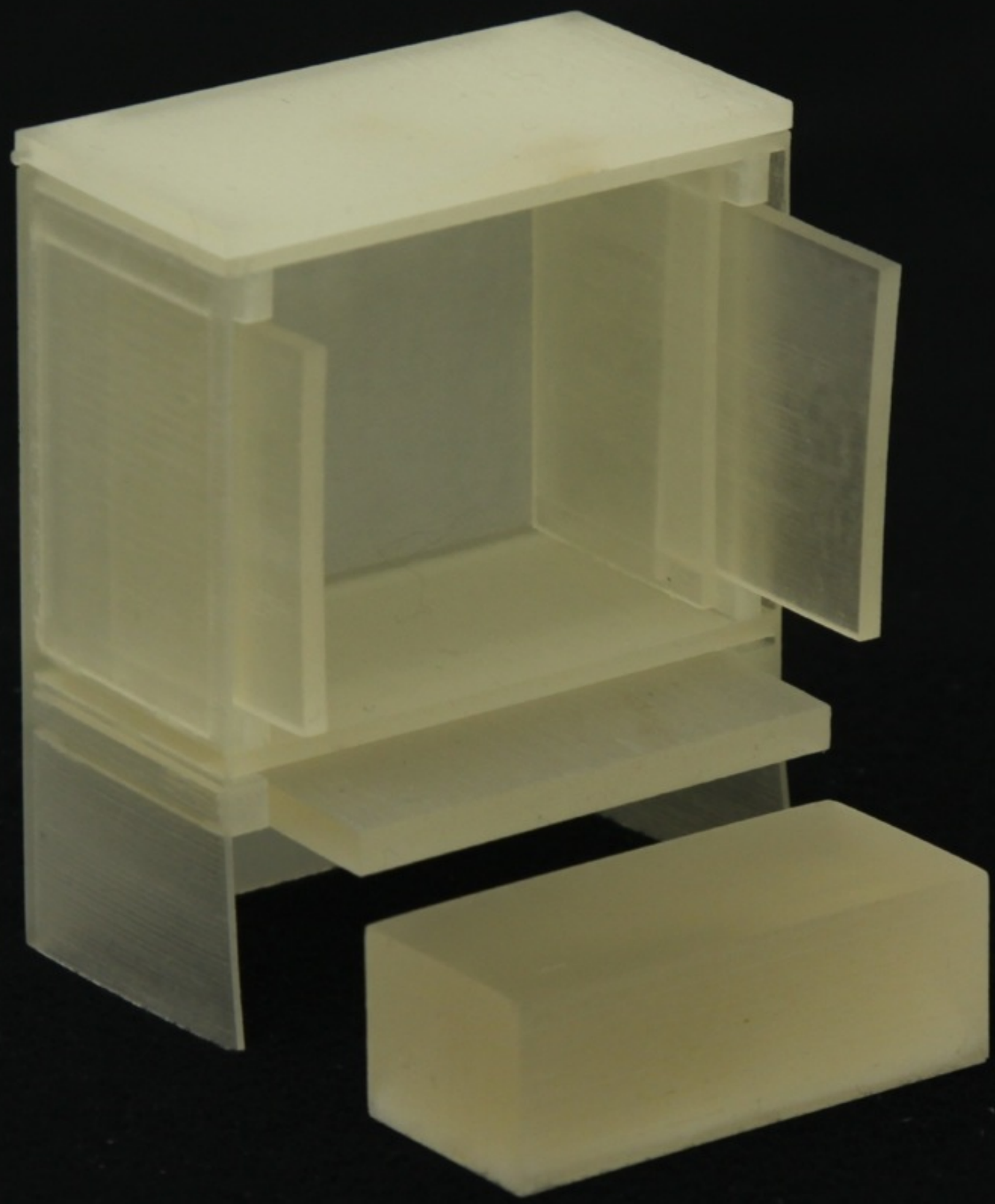
Cavities



Ready-to-fabricate models

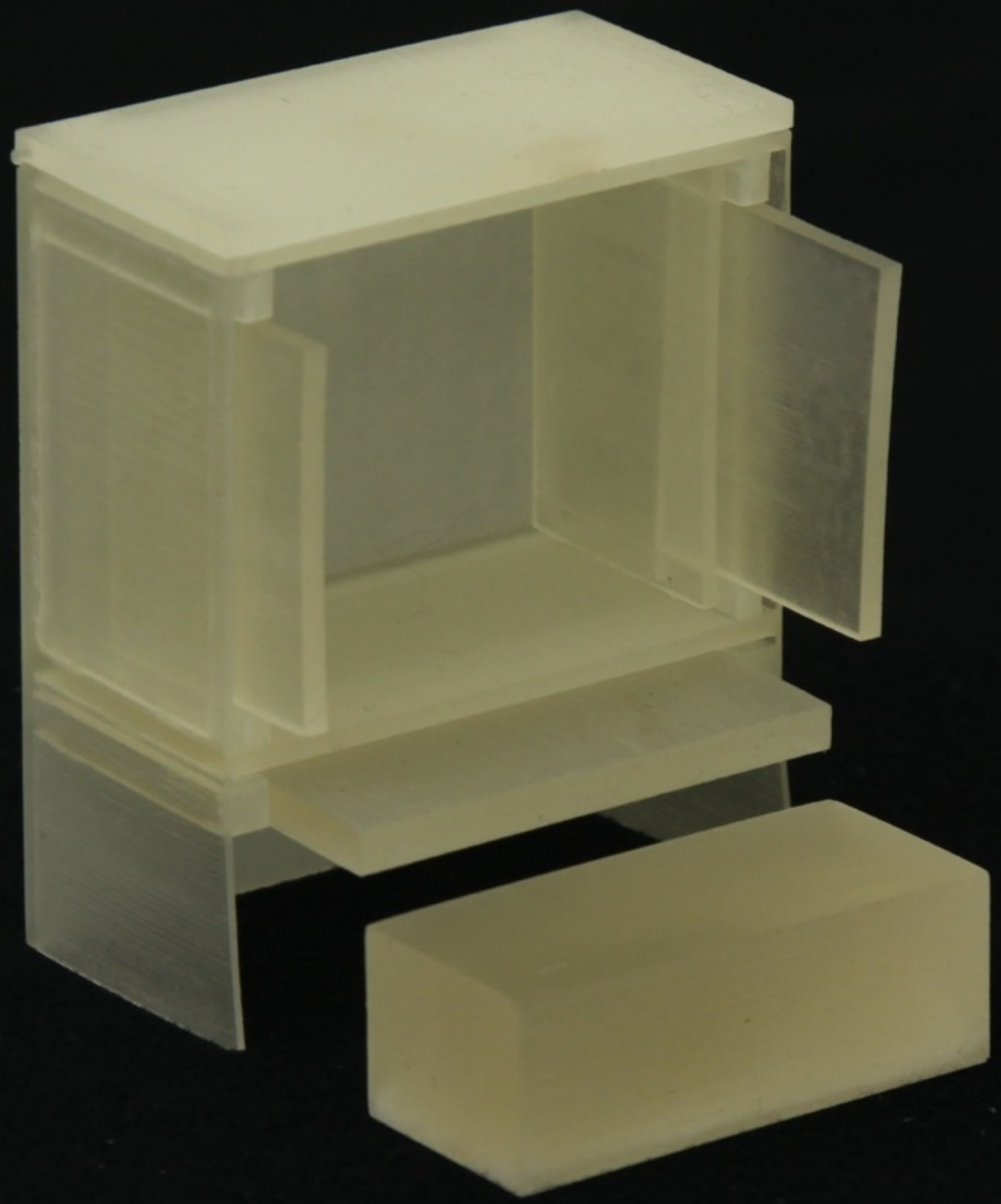
Cavities

Joint geometry

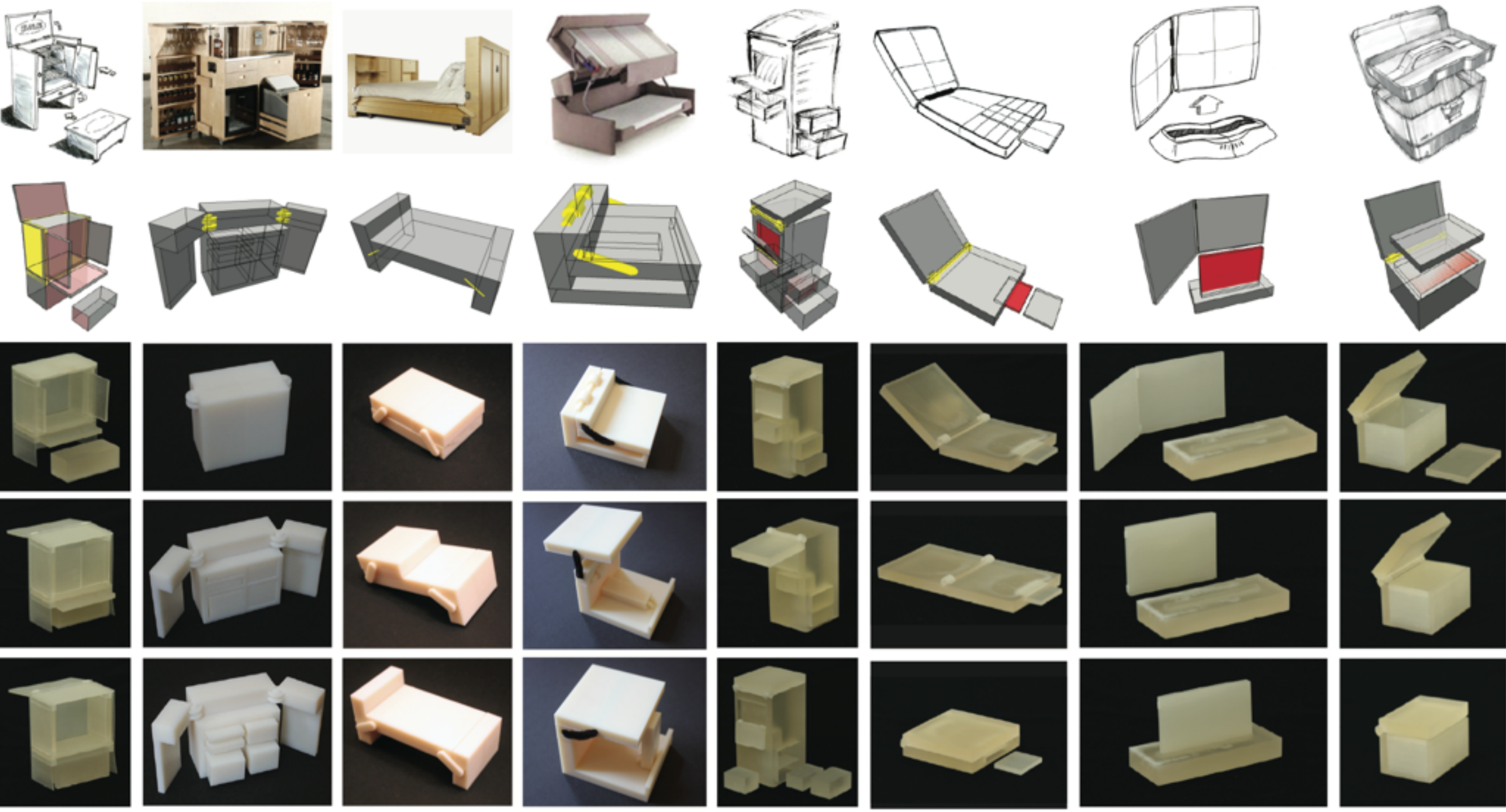


Ready-to-fabricate models

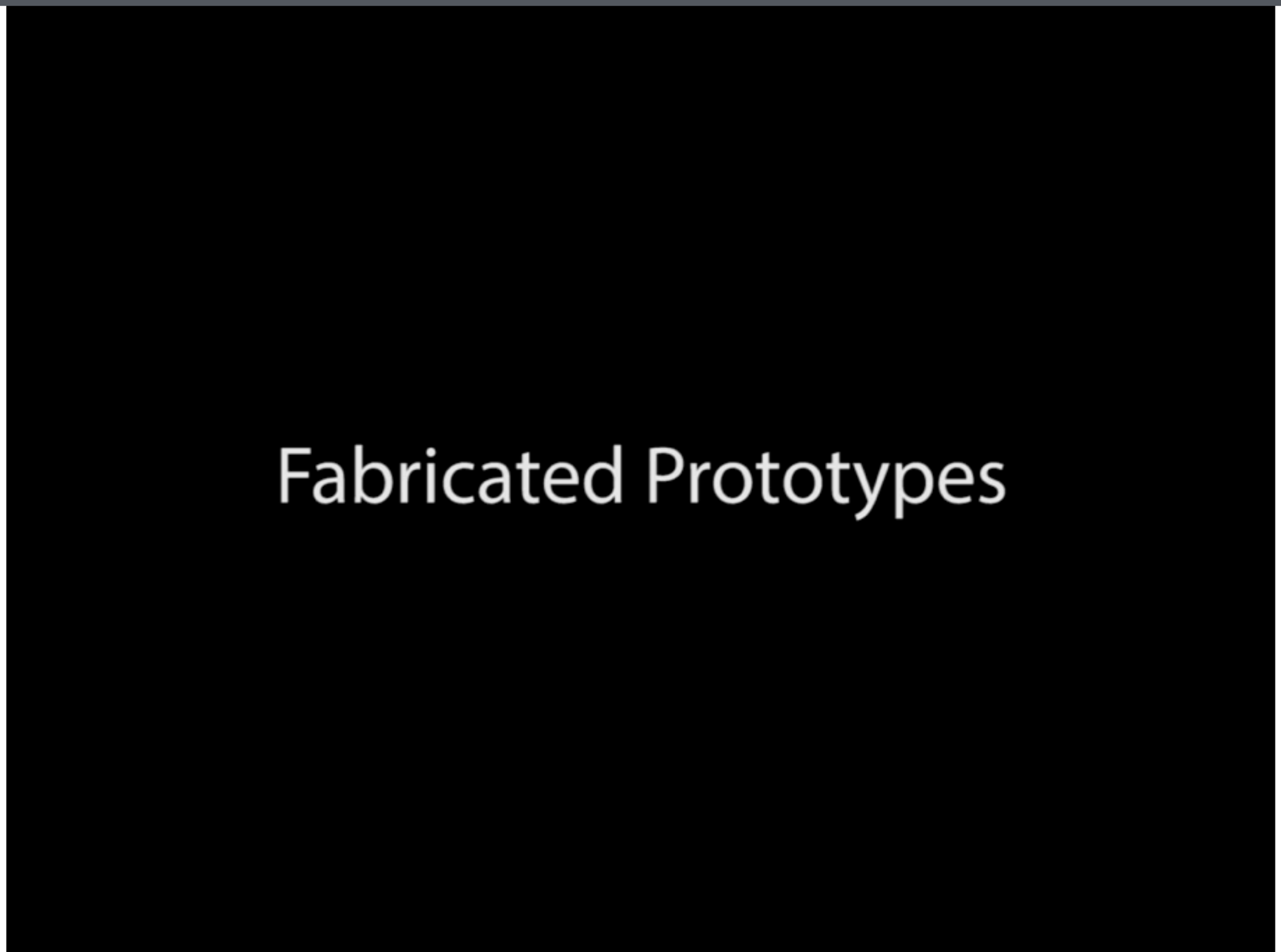
- Cavities
- Joint geometry
- Gaps



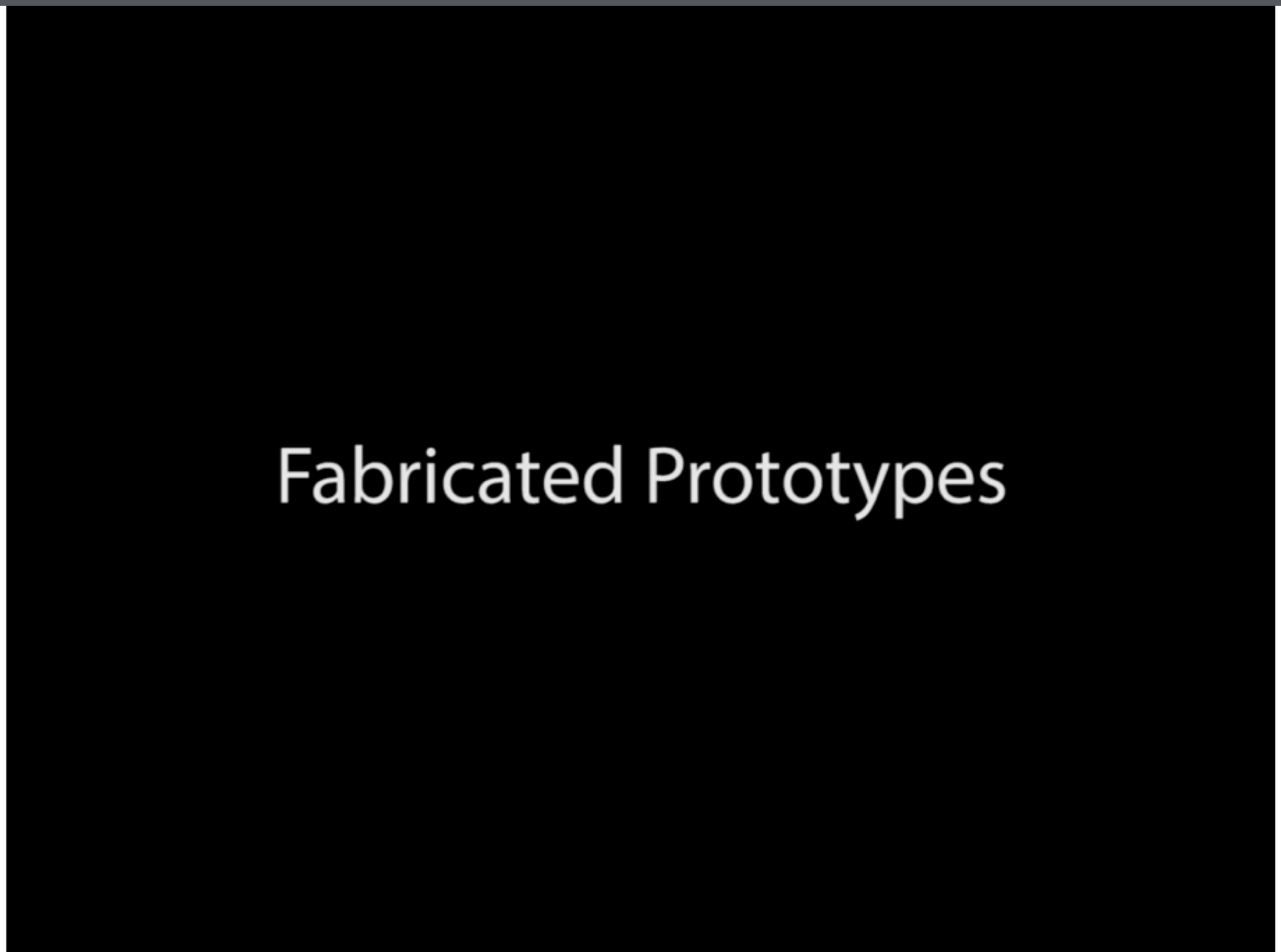
Results



Results



Results



Limitations

Limited part and joint types

Limitations

Limited part and joint types

Few functional relationships

Thanks!

Model STLs available on:

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