

Declarative Design

Jonathan Bachrach

EECS UC Berkeley

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- introduce declarative design – what not how?
- seedlings

- lab 5 due thursday
- two more weeks of lecture
- then project proposals

Low Chair by Martin Ohlson

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Fine Chair by Olle Gustafsson



Barcelona Chair

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Metal Chair 1930

6



Bamboo Chair by Brave Space Designs

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- each chair takes a huge effort to design and fabricate
- need to quickly explore design space
- explore as much as possible to ensure best design
- somehow specify requirements

What is a Chair?

chair  [chair]  [Show IPA](#)

noun

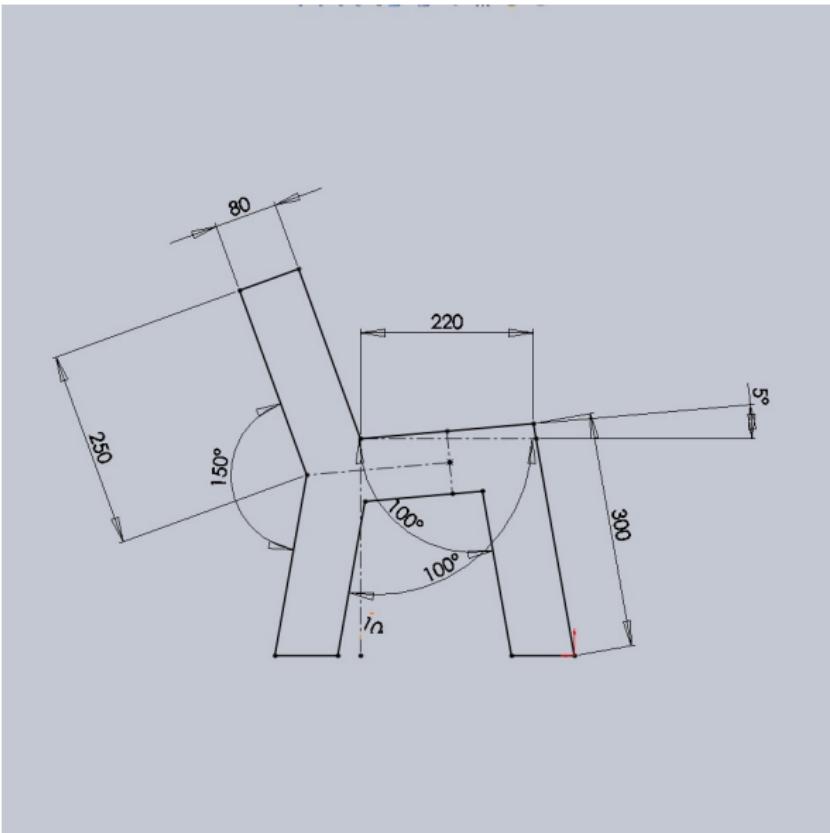
1. a seat, especially for one person, usually having four legs for support and a rest for the back and often having rests for the arms.



With four parameters I can fit an elephant, and with five I can make him wiggle his trunk – Von Neumann

Chair Degrees of Freedom

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Chair Sketch One

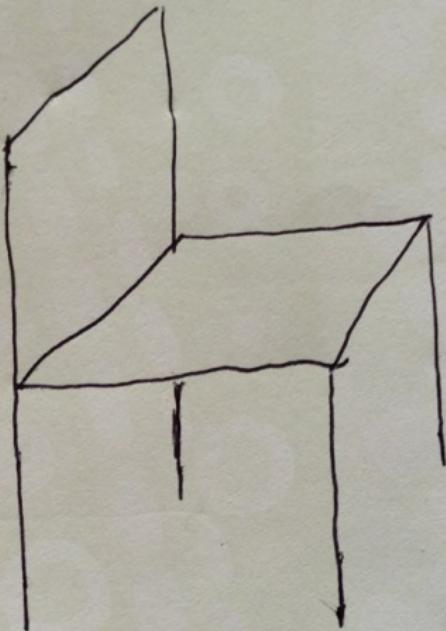
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CANEEL BAY

A ROSEWOOD RESORT

ST. JOHN, U.S. VIRGIN ISLANDS



Chair Sketch Two

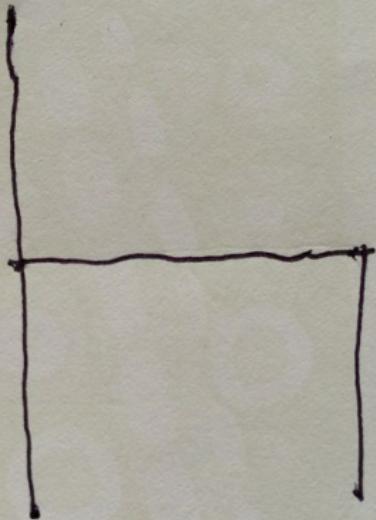
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canefel bay

A ROSEWOOD RESORT

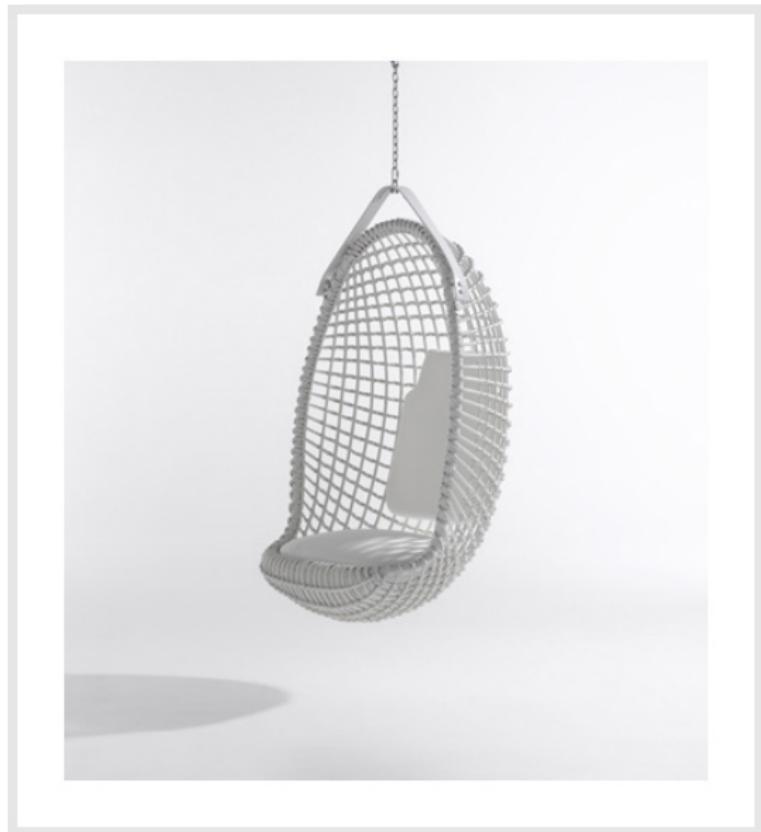
ST. JOHN, U.S. VIRGIN ISLANDS





Hanging Chair by Giovanni Travasa

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Supported Hanging Chair by Yahki Rattan

17



Bar Chair by Pierre Paulin

18



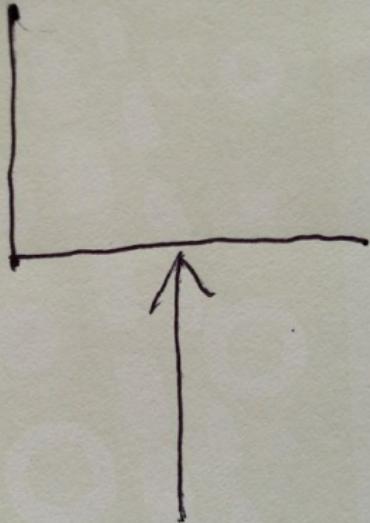
Pole Chair by Nicola Trudgen

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Chair Sketch Three

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Chair Sketch Four?

Flat Chair by Sarah Fisher Paculdo

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Folding Chair by Brain Stream Design Studio

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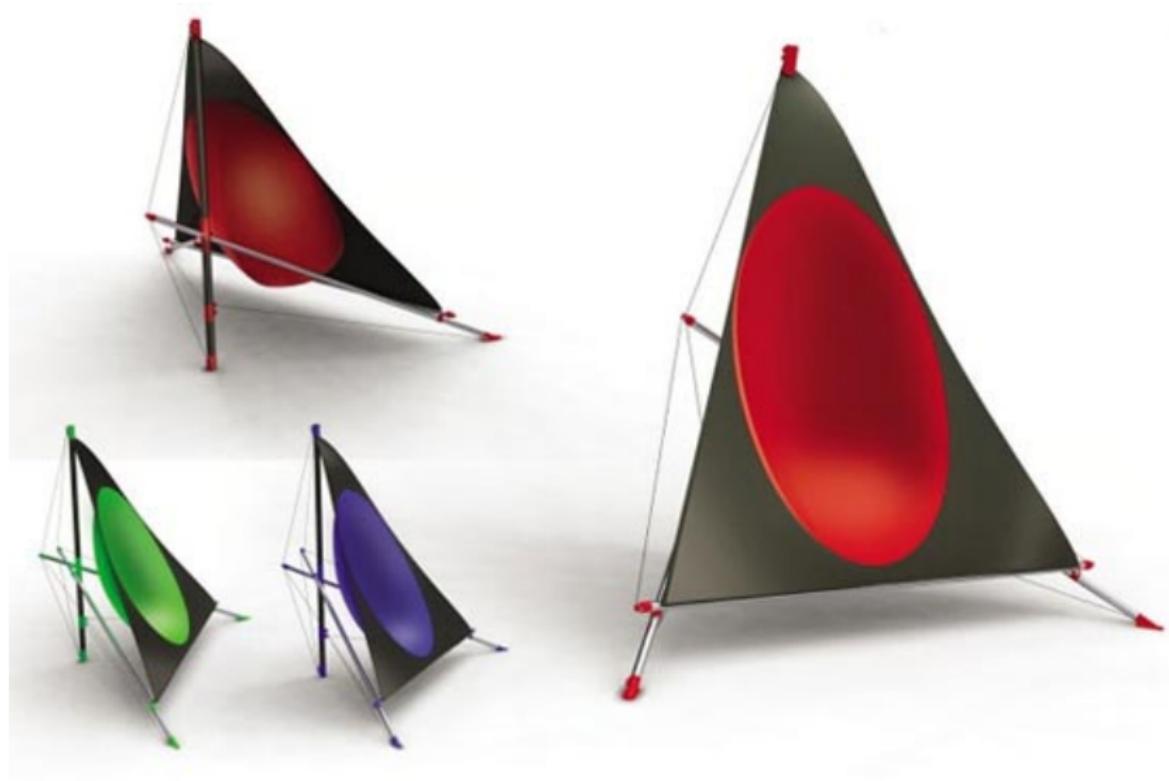
Accordion Chair by Chishen Chiu

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Lightweight Chair by Mark Hagen

25



Storage Chair by Fishbol Furniture

26



Beautiful Chair by Michael Bihain

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- know one when we see one ...
- *obviously if articulating what we like is helpful*
- but want to find design ...

- need more computational expression of goodness
- need to be able to measure (un)desireable properties
- need to be able to combine measures

- explore design space
- find best design point(s) while
- minimizing computation

Find Chair Voxels

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remove non chair voxels

- completeness
- minimality
- coverage
- efficiency

- Evolutionary – by example
- Generative Grammars
- Procedural Generators

Fit and Diverse: Set Evolution for Inspiring 3D Shape Galleries

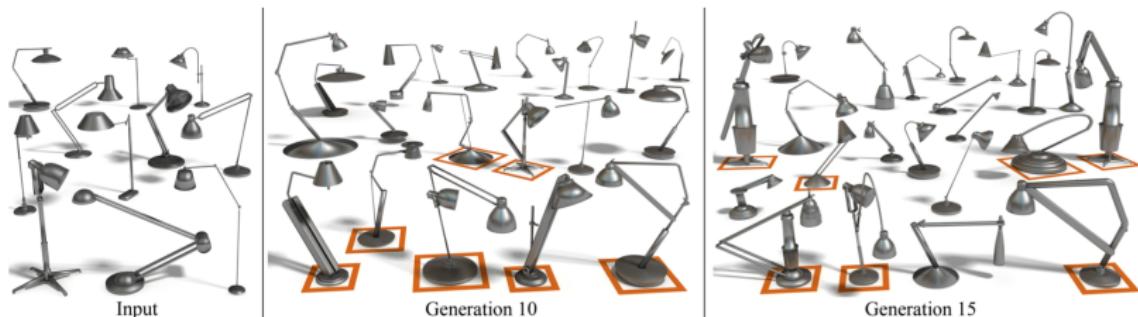
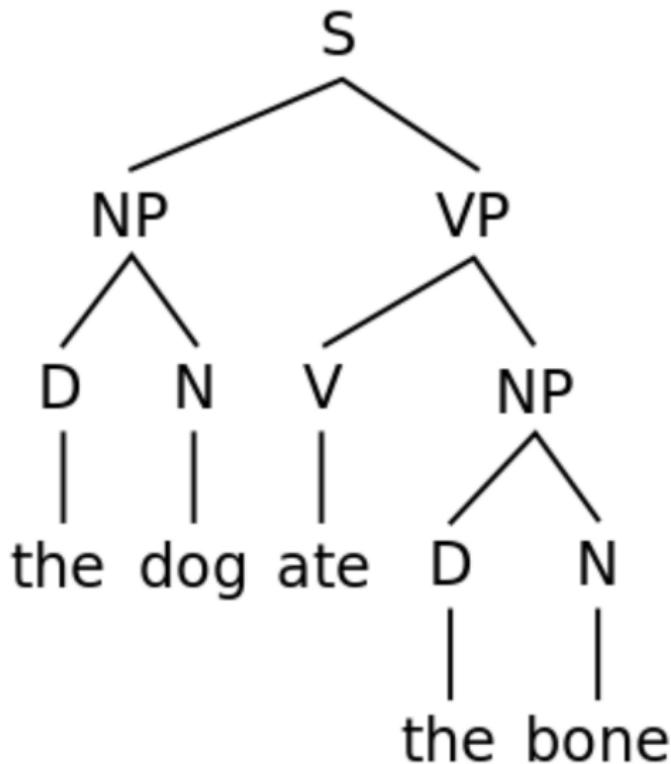
Kai Xu^{*†}Hao Zhang[‡]Daniel Cohen-Or[§]Baoquan Chen^{*}^{*}Shenzhen VisuCA Key Lab/SIAT [†]National University of Defense Technology (NUDT)[‡]Simon Fraser University[§]Tel-Aviv University

Figure 1: Set evolution starting from a small input set of lamps (left). With the set evolution “fit and diverse”, new generations of shapes are not only fit to be lamps but also exhibit significant and potentially inspiring variations.

Chair Grammar?

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generally

- generate candidates
- collect best based on goodness

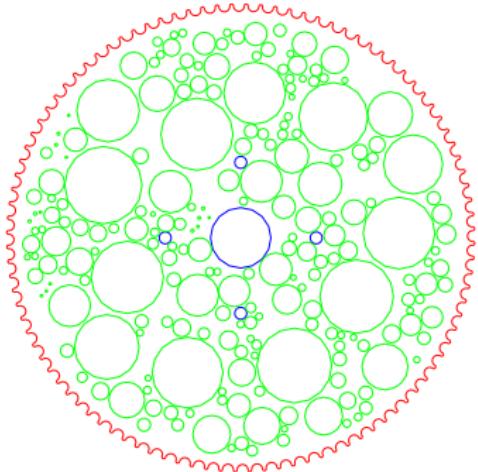
want to

- avoid generating bad candidates

- support
- strength to weight
- size
- etc

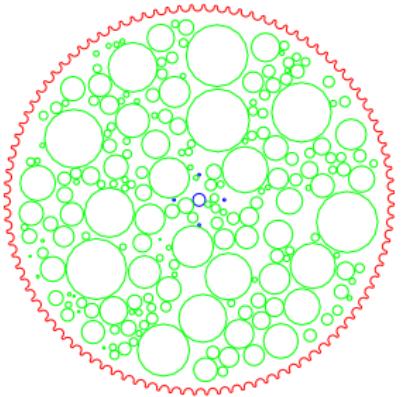
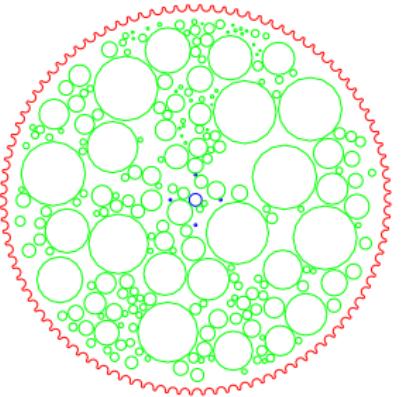
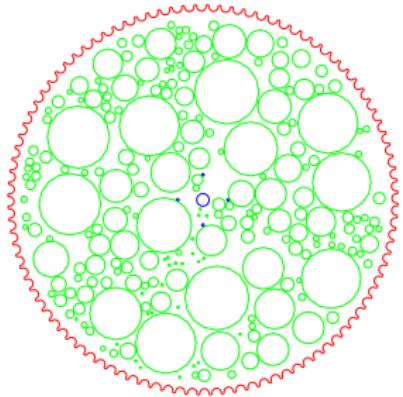
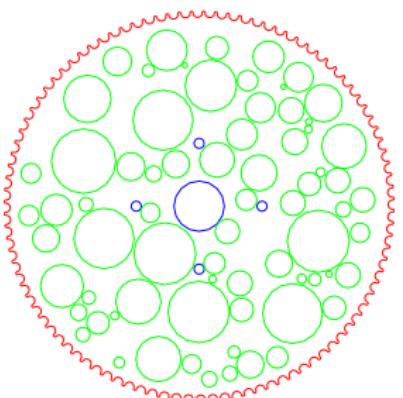
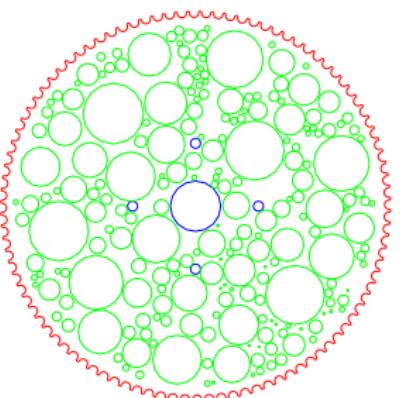
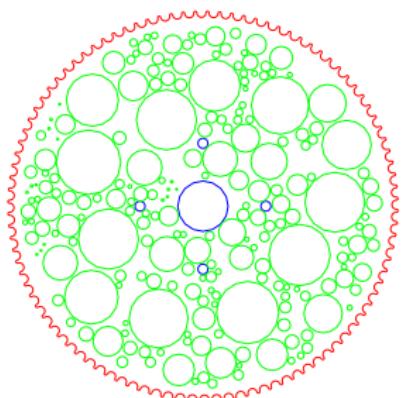
translate into measurable entity

- want speed holes in crank
 - varied
 - balanced
 - given density
 - avoid screw holes
- random speed holes is too slow
- how to write tractable generator?



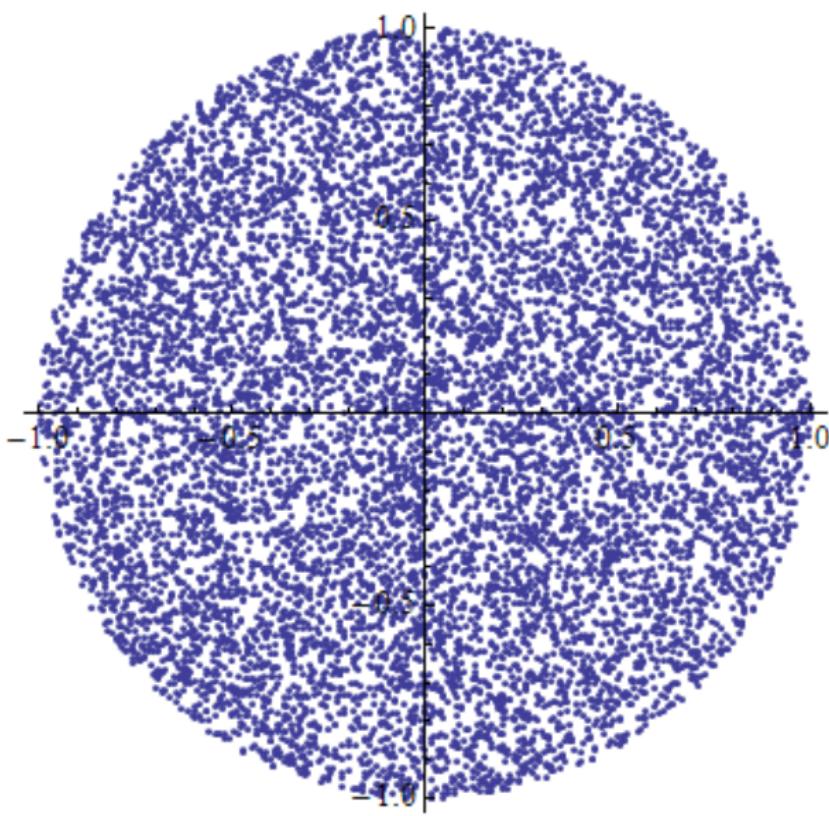
Holy Crank Outputs

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Uniform Point in Circle

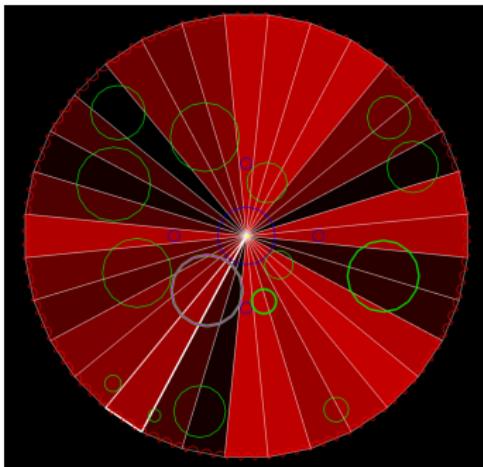
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Holy Crank Solution

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- divide crank into pie slices
- sample according to density
- maintain free list
- only add hole if it improves balance



- gear -step :density 0.5 :num-speed-holes 100

- placement of furniture optimized
- moves – translation and rotations
- cost function
- simulated annealing

functional criteria

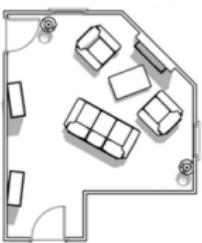
- clearance
- circulation
- conversation

visual criteria

- balance
- alignment
- emphasis



(a) Clearance and reachability term excluded



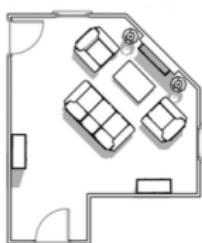
(b) Alignment term excluded



(c) Emphasis term excluded



(d) Conversation and pairwise terms excluded

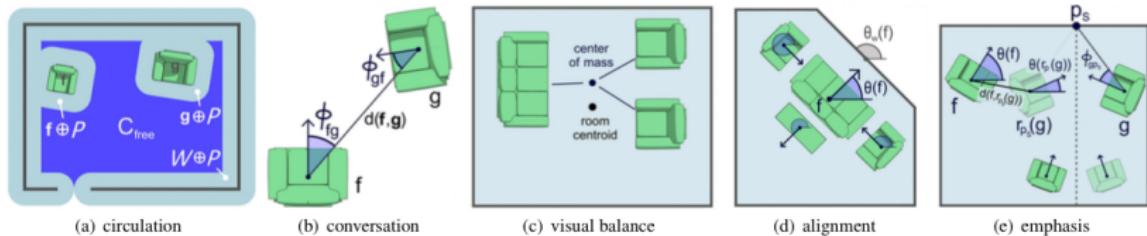


(e) All terms included

merrell + schkufza + li + agrawala + koltun

Individual Terms

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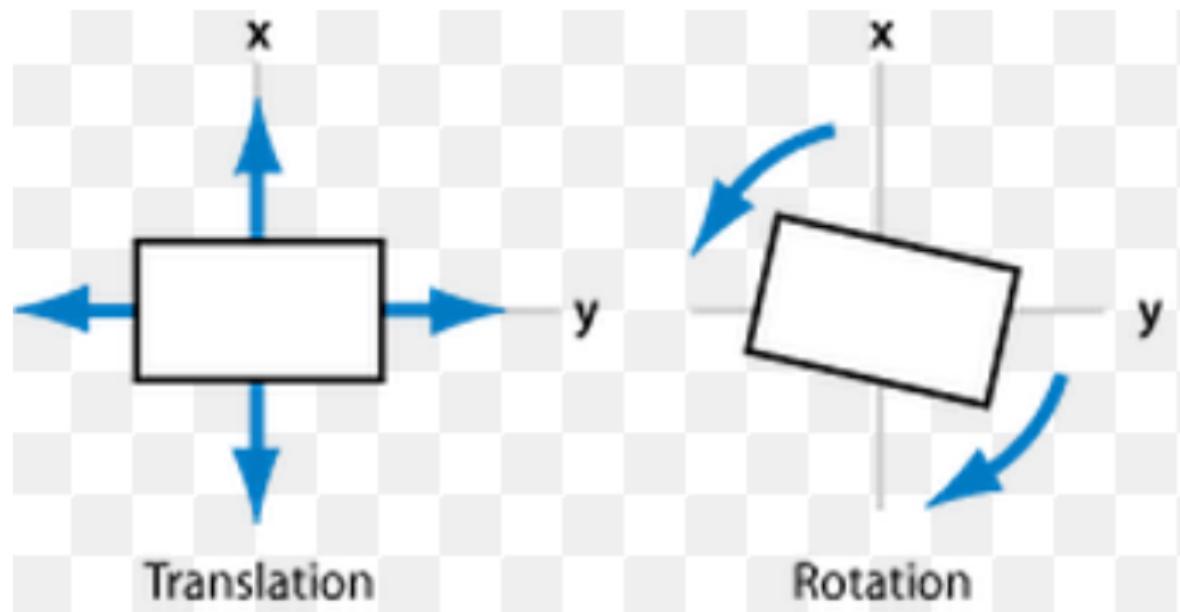
The seats should also be angled towards each other to encourage eye contact. The conversation angle term is formulated as

$$m_{ca}(\mathcal{I}) = - \sum_{S \in \mathcal{G}} \sum_{f,g \in S} q_{fg} (\cos \phi_{fg} + 1) (\cos \phi_{gf} + 1),$$

where ϕ_{fg} is the angle between object f and object g (Figure 5(b)).

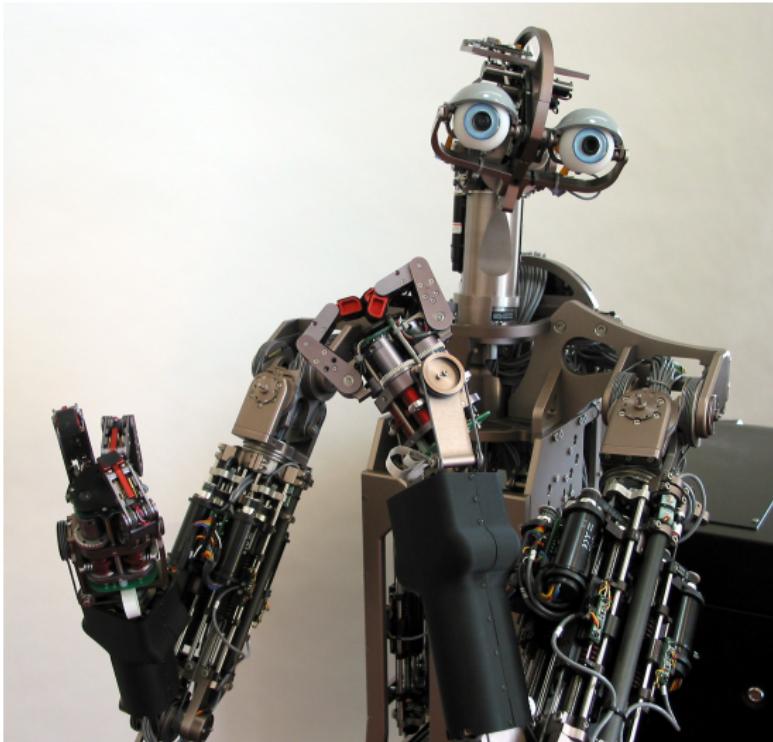
```
T <- initial temperature
L <- initial layout
C <- cost( layout )
until (equilibrium reached)
  S,M <- choose stencil,move
  L' <- L + S,M // move and relayout
  C' <- cost(L') // update cost
  if ((C' - C) is acceptable)
    L <- L'
  T <- schedule(T)
```

- translation
- rotations



Robot Design is Absurd

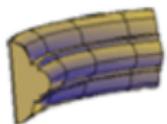
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domo by meka robotics

- skeletal specification
- transformations
- **smaller search space!**
- *reduced degrees of freedom*

- draw in 2d – extrude into 3d
- easier and more robust than 3d modeling



sweep



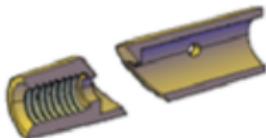
extrusion



revolve



loft



slice



conversion



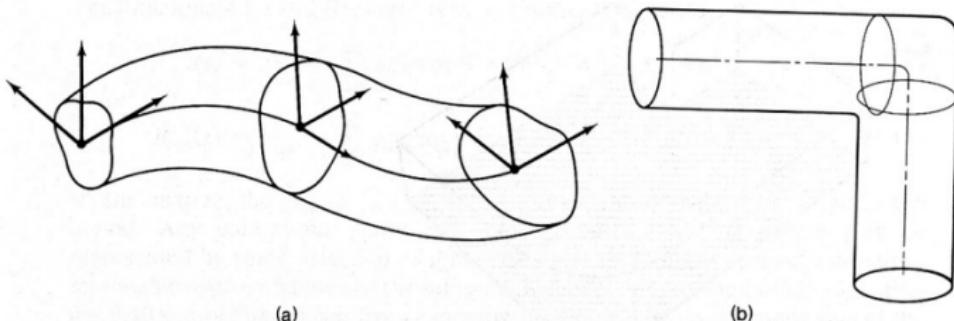


Fig. 9.12 (a) A generalized cylinder and some cross-sectional coordinate systems. (b) A possibly “pathological” situation. Cross sections may be simply described as circles centered on the axis, but then their intersection makes volume calculations (for instance) less straightforward.

ballard + brown

- build system out of abstract functions
- say what it does but not how
- place holders for efficient implementations

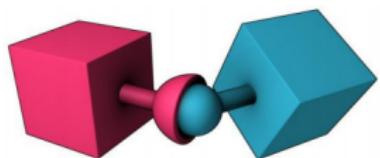


Figure 3 Point to point constraint

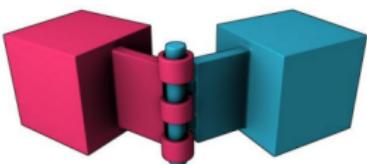


Figure 4 Hinge Constraint

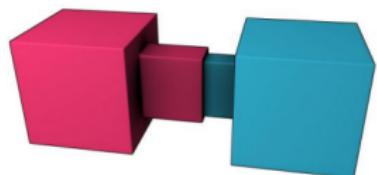
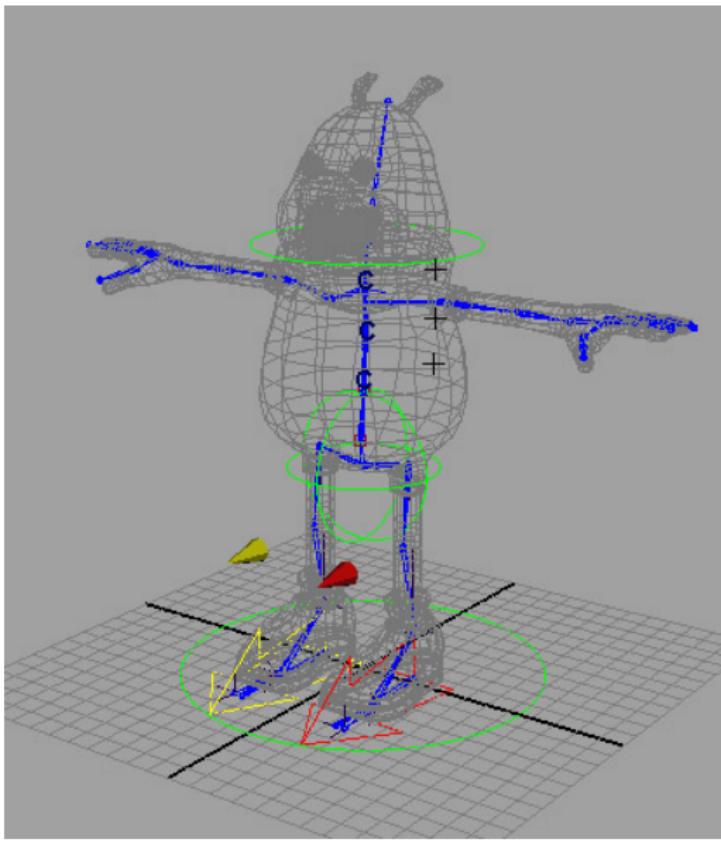


Figure 5 Slider Constraint

bullet physics manual

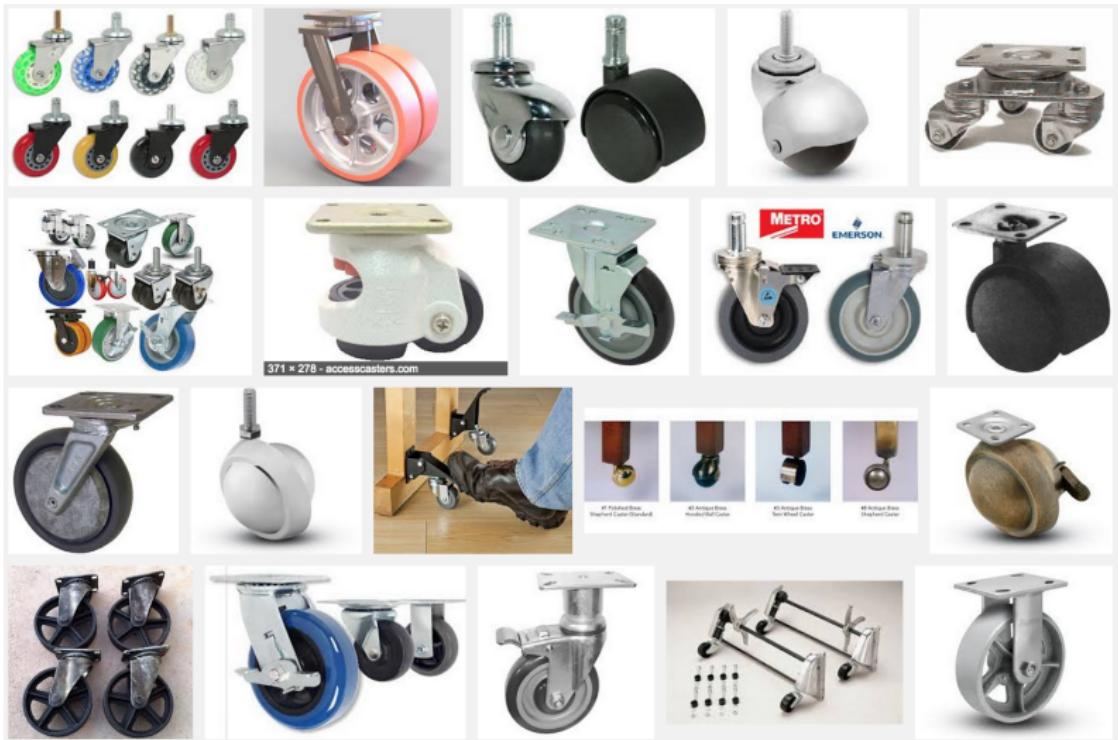


Tubbrit

Furniture Components

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- casters
- pulls



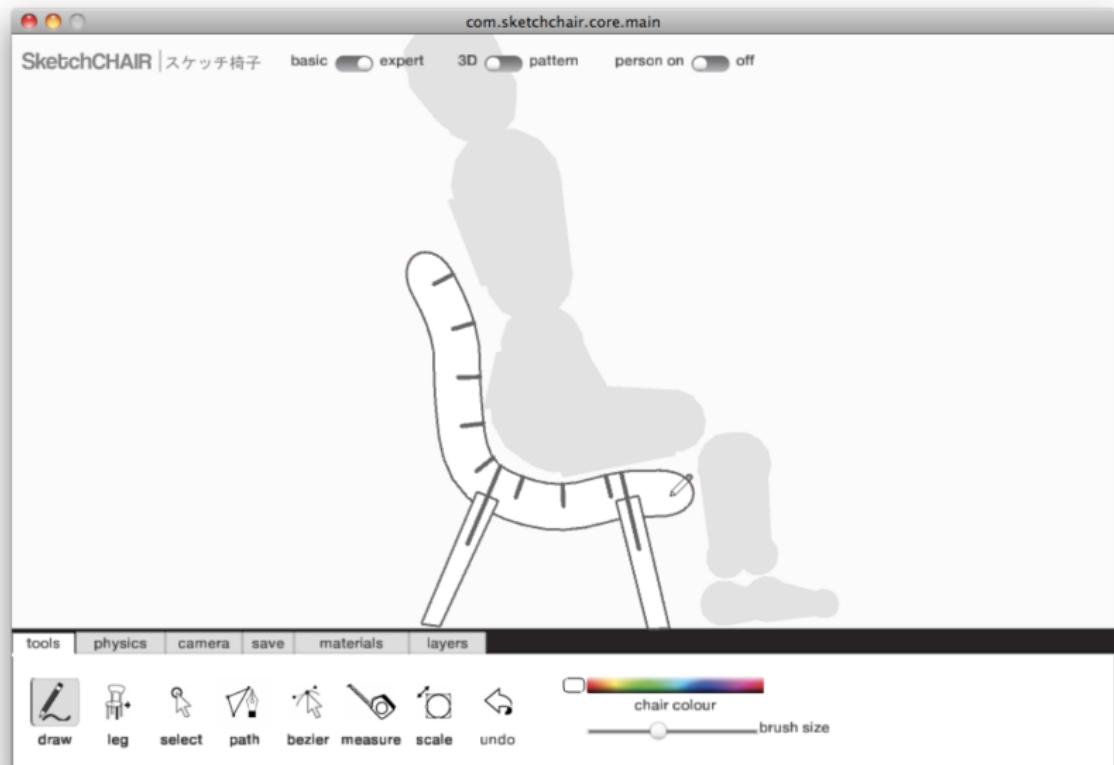
- reduced search space
- keeps design higher level and intuitive
- separates concerns
- encourages modularity
- powerful lower dimensional generator

- generative design
- design space exploration

- what not how is powerful
- specification language
- tractable generation of candidates
- computational goodness (and aesthetics)
- searching good designs

Fabricate Less – Simulate More

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sketch chair

- *Make It Stand: Balancing Shapes for 3d Fabrication* by Prevost, Whiting, Lefebvre, Sorkine-Hornung
- *Interactive Furniture Layout Using Interior Design Guidelines* by
- *Make It Home: Automatic Optimization of Furniture Arrangement* by Yu, Yeung, Tang, Tezopoulos, Chan, Osher
- *Halide: Decoupling Algorithms from Schedules for Easy Optimization of Image Processing Pipelines* by Ragan-Kelley, Barnes, Adams, Paris, Durand, Amarasinghe
- *Spec2Fab: A Reducer-Tuner Model for Translating Specifications to 3D Prints* by chen, levin, didyk, sitthi-amorn, matusik
- *Computational Design of Mechanical Characters* by Coros, Thomaszewski, Noris, Sudea, Forberg, Sumner, Matusik, Bickel
- sketch chair <http://www.sketchchair.cc>

- weight versus strength
- weight versus stability
- durability versus price
- comfort versus style

- how do we specify preferences?
- some are soft and others are hard
- how do we measure success?

- explore design space
- find best design point
- minimizing computation