Declarative Design

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October 13, 2015
introduce declarative design – what not how?
seedlings
- Lab 5 due Thursday
- Two more weeks of lecture
- Then project proposals
Low Chair by Martin Ohlson
Barcelona Chair
Metal Chair 1930
Bamboo Chair by Brave Space Designs
Design Problem as Optimization

- 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
Chair Sketch Two
Hanging Chair by Giovanni Travasa
Bar Chair by Pierre Paulin
Pole Chair by Nicola Trudgen
Flat Chair by Sarah Fisher Paculdo
Folding Chair by Brain Stream Design Studio
Accordian Chair by Chishen Chiu
Storage Chair by Fishbol Furniture
Beautiful Chair by Michael Bihain
How Do We Express Definition?

- 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 Voxel

remove non chair voxels
Generative Challenges

- completeness
- minimality
- coverage
- efficiency
Tractable Generators

- Evolutionary – by example
- Generative Grammars
- Procedural Generators
Fit and Diverse: Set Evolution for Inspiring 3D Shape Galleries

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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.
The diagram represents a sentence in generative grammar. The sentence is "the dog ate the bone." The tree structure shows the constituents of the sentence:

- **S** (sentence)
- **NP** (noun phrase) for "the dog"
- **VP** (verb phrase) for "ate the bone"

The diagram breaks down as follows:

- **NP** (noun phrase) for "the dog" has components:
  - **D** (determiner) for "the"
  - **N** (noun) for "dog"

- **VP** (verb phrase) for "ate the bone" has components:
  - **V** (verb) for "ate"
  - **NP** (noun phrase) for "the bone" has components:
    - **D** (determiner) for "the"
    - **N** (noun) for "bone"
Design Space Exploration

- generally
  - generate candidates
  - collect best based on goodness

want to

- avoid generating bad candidates
Chair Goodness Function

- 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?
Uniform Point in Circle
- 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
Furniture Layout

- placement of furniture optimized
- moves – translation and rotations
- cost function
- simulated annealing
functional criteria
- clearance
- circulation
- conversation

visual criteria
- balance
- alignment
- emphasis

merrell + schufza + li + agrawala + koltun
The seats should also be angled towards each other to encourage eye contact. The conversation angle term is formulated as

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

where \( \phi_{fg} \) is the angle between object \( f \) and object \( g \) (Figure 5(b)).
Simulated Annealing Algorithm

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
- skeletal specification
- transformations
- smaller search space!
- reduced degrees of freedom
2d -> 3d – Extrusions

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

Figure 3 Point to point constraint

Figure 4 Hinge Constraint

Figure 5 Slider Constraint

bullet physics manual
Rigging

Tubbrit
Furniture Components

- casters
- pulls
Multiple Advantages

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

- generative design
- design space exploration
what not how is powerful
■ specification language
■ tractable generation of candidates
■ computational goodness (and aesthetics)
■ searching good designs
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
- 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
Tradeoffs

- 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