OUTLINE

- Administrative Details:
  - Slides from guest lecturer Pejman Nowzad posted along with his reading list and recommended company profiles
  - This week: Notes from Weekly Meeting.
  - Next week: Morphological Chart. Set of team member sketches for the Gallery Method. Notes from Weekly Meeting.
  - See email on Tesla field trip: depart Stanford 1:45 on March 3
    - You will need: closed-toe shoes and sleeved shirts, to sign an NDA, and to complete Nathan’s assignment in advance

- Lecture
  - Generating and Evaluating Design Ideas

- Speaker
  - Laurie Yoler
GENERATING & EVALUATING DESIGN IDEAS
EVERYTHING SHOULD BE MADE AS SIMPLE AS POSSIBLE BUT NOT SIMPLER.

Albert Einstein
FROM IDEA TO PRODUCT

Generating

Problem Statement

Selecting

What gets built.
What is our problem statement?
DESIGN SPACE OF JUICE CONTAINER

Conceptualization of a space that incorporates all possible designs.

Juice Container Design Space

Cardboard Box
Plastic Bag
Plastic Bottle
Glass Bottle
Aluminum Can

Straw Hole
Twistoff Cap
Metal Cap
Pullring
Pushtab
S-LIGHT PROJECT

KEY OBJECTIVES

- Allow users to locate bicycles on crowded bike racks
  - Both daytime and nighttime conditions
  - From at least 50 feet away
  - By using both auditory and visual elements
- Implement the solution using a device that is not bulky or heavy on the bicycle
- Implement the solution using a device that is no more than double the cost of existing bike lights
  - This price should account for lights, speakers, and remotes
## EXAMPLE OF DESIGN SPACE – S-LIGHT PROJECT

### Light Set-Up
- Rotating Light
- Lights Around Outside
- Rotating Cover with Slit

Brightest, Ability to Customize, No moving parts

### Activation of Tracking System
- Whistle Recognition
- Voice Recognition
- Remote Control

50 Foot Range, Convenient Size, No possibility of confusion

### Attachment
- Mounting Bracket
- Welding

Conventional, Cheap, Freedom to remove from bike
A problem has a large design space if

- The number of potential designs is large
- The number of design variables and/or the number of values they can assume is large

Artifacts with large design spaces

- Airplanes
- Buildings
- ...

By contrast, what has a small design space?
DESIGN SPACE DECOMPOSITION EXAMPLE: AIRPLANE

- Airplane
  - Passenger Compartment: Seats, Emergency Exits
  - Fuselage: Overhead Bins
  - Wings: Seats
  - Kitchen: Windshields
  - Cockpit: Controls
MORPHOLOGICAL CHART: ORGANIZING FUNCTIONS & MEANS

- List of functions or features.
- List of different means of each function or feature identified.
- Assemble designs in the classic *Chinese Menu* style.
Problems

- Lacks synchronization
- Lack of applications/devices designed specifically for students
- Failure to understand students well

Our Goals

- One integrated app for the iPad
- Targeted specifically at college students
- Intelligent syncing & searching
- Bring together all the advantages
- Unprecedented social utilities
# ELLIPSIS MORPH CHART

<table>
<thead>
<tr>
<th>Function</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Platform</strong></td>
<td><strong>Tablet</strong></td>
</tr>
<tr>
<td><strong>Navigation</strong></td>
<td>Main Menu</td>
</tr>
<tr>
<td></td>
<td>Tabs on Screen</td>
</tr>
<tr>
<td></td>
<td>Cluster Chart</td>
</tr>
<tr>
<td></td>
<td><strong>Marking Menu</strong></td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td><strong>Type</strong></td>
</tr>
<tr>
<td><strong>Options</strong></td>
<td><strong>Write</strong></td>
</tr>
<tr>
<td></td>
<td>Voice Commands</td>
</tr>
<tr>
<td><strong>Packaging</strong></td>
<td>One Bundle</td>
</tr>
<tr>
<td></td>
<td>Different Modules</td>
</tr>
<tr>
<td></td>
<td>Free Module with Add-on Options</td>
</tr>
<tr>
<td></td>
<td><strong>Core Module with Add-on Options</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Subscription</strong></td>
</tr>
<tr>
<td></td>
<td>Completely Free</td>
</tr>
</tbody>
</table>
DIVERGENCE VS CONVERGENT THINKING

- **Divergent thinking:**
  - Try to remove limits or barriers on design ideas
  - Think outside the box

- **Convergent thinking:**
  - Narrowing the design space to focus on the best alternatives
  - Know the constraints and boundaries to converge on a solution within these limits.

Think outside the box, but stay within the laws of physics!
TEAM METHODS (n members)

- **n:3:n-1 (in book it is 6-3-5):**
  - Each member writes 3 ideas.
  - n lists rotated among n-1 team members
  - Each member comments on each idea

- **C-sketch:**
  - Same as n:3:n-1 method, but rather than listing 3 ideas, sketch 3 pictures.

- **Gallery:**
  - Each member does 1 sketch of a design idea
  - Sketches posted, then each discussed by team

Gallery sketches due 2/17
EXPANDING YOUR DESIGN SPACE

- Talk to experts that work on related designs
- Product literature on existing products
- Visionary/research papers and articles
- Design and legal codes
- Standards (often based on performance analysis available in the standards literature)
- WWW search
- Patent search (www.uspto.gov, google.com/patents, freepatentsonline.com)
- Benchmark existing products to evaluate how well they perform.
- Reverse engineer or dissect existing devices
CONTRACTING YOUR DESIGN SPACE

- Check for external constraints that affect the design
- Invoke and apply constraints
- Freeze the number of features and behaviors being considered
- Impose priorities on the list of features and functions
- Apply common sense to rule out infeasible ideas.
SELECTING THE BEST DESIGN

- Now you have a number of feasible design alternatives
- How do you select the best design?
Want a design that best meets a client’s objectives
Use metrics to determine how well a design meets objectives
Should focus on client’s most important objectives
Designs that don’t meet constraints must be rejected
Methods for Design Evaluation via Metrics (2 out of 3 due 3/1)
- Numerical Evaluation Matrix
- Priority Checkmarks
- Best of Class Chart

Use Common Sense When Looking At Results!
NUMERICAL EVALUATION MATRIX

- Shows both constraints (upper rows) and objectives (lower rows) in the left-hand column
- Eliminate designs that don’t meet constraints
- Assign a score to each remaining design for each objective (pick a useful, differentiating scale like 1-10 or 1-100)
- See if “best design” is clear from the scoring (best/equal in all areas)
- Determine (with client) which design best meets ranked objectives
TABLE 8.1 A *numerical evaluation matrix* for the juice container design problem. Note that only three of the six objectives originally identified for this design are utilized here, in part because we think these three objectives are more important than the other three, and in part because we have metrics (and presumably data) for these three objectives.

<table>
<thead>
<tr>
<th>Design Constraints (C) and Objectives (O)</th>
<th>Glass Bottle, with Twist-Off Cap</th>
<th>Aluminum Can, with Pull-Tab</th>
<th>Polyethylene Bottle, with Twist-Off Cap</th>
<th>Mylar Bag, with Straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>C: No sharp edges</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C: Chemically inert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O: Environmentally benign</td>
<td></td>
<td></td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>O: Easy to distribute</td>
<td>40</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O: Long shelf life</td>
<td>90</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Simpler, qualitative version of the numerical evaluation matrix

- Rank objectives as high (3 checks), medium (2 checks) or low (1 check)
- Assign design a 1 if meets objectives well, otherwise a 0
- Scoring times number of checks yields total checks per objective

As with NEM, see if “best design” is clear from the scoring based on ranked objectives
**TABLE 8.2** A *priority benchmark chart* for the juice container design problem. This chart qualitatively reflects a client’s values in terms of the priority assigned to each objective, so it uses the ordering in the PCC of Figure 4.4.

<table>
<thead>
<tr>
<th>Design Constraints and Objectives</th>
<th>Priority (✓)</th>
<th>Glass Bottle, with Twist-Off Cap</th>
<th>Aluminum Can, with Pull-Tab</th>
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<td></td>
<td></td>
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</tr>
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<td>O: Environmentally benign</td>
<td>✓✓✓</td>
<td></td>
<td></td>
<td>1 ✓✓✓✓</td>
<td>0 ✓✓✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓✓✓</td>
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<td>0 × ✓</td>
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<td>1 × ✓</td>
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<td></td>
<td></td>
<td></td>
<td>☀ ☀ ☀ ☀</td>
<td></td>
</tr>
<tr>
<td>O: Long Shelf Life</td>
<td>✓✓</td>
<td>1 ✓✓</td>
<td></td>
<td>1 ✓✓</td>
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<td></td>
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<td>☀ ☀ ☀ ☀</td>
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</tr>
</tbody>
</table>
### BEST OF CLASS CHART

- For each objective, assign scores to each design alternative
- Scores start from 1 for the alternative that meets that objective best, increasing to 2 for second-best, and so on
- Ties equally split their combined score, e.g. best 2 designs are each assigned \((1+2)/2=1.5\), 3 designs tied for second get \((2+3+4)/3=3\)

As with NEM, see if “best design” is clear from the scoring based on ranked objectives
TABLE 8.3  A *best-of-class chart* for the juice container design problem. This chart presents the rank ordering of the metrics results for each acceptable design. Notice that in this case, the client and the designer will need to select between the winner for the highest objective, or a design that wins on both of the other ones.

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<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>O: Easy to distribute</td>
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<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
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<td></td>
<td>2</td>
<td>1</td>
<td></td>
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DESIGN FOR X

Where X is an attribute:

- Production
- Affordability
- Long-term Use
- Sustainability
DESIGN FOR PRODUCTION

- Production entails manufacture and assembly
- Bill of Materials (BoM)
  - List of all parts going into the design, and their cost
- Assembly Chart
  - Order in which the materials in the BoM are assembled
  - Use to determine timing for purchase orders (just in time)
- Production goal
  - Minimize cost of production and/or time to market
  - While maintaining an appropriate level of quality
  - And keeping costs down
DESIGN FOR MANUFACTURE AND ASSEMBLY

**Design for Manufacture (6 steps)**
- Estimate manufacturing costs for a given design
- Reduce costs of components
- Reduce costs of assembly
- Reduce cost of supporting production
- Consider effects of DFM on other objectives
- If results are not acceptable, revise design again

**Design for Assembly**
- Limit number of components, make them easy to retrieve, assemble and repair
- Use standard fasteners
- Use a base component
DESIGN FOR AFFORDABILITY, LONG TERM USE, AND SUSTAINABILITY

- **Affordability:** True Cost = Initial Purchase Costs + Operating & Maintenance Costs over Life of Device
  - Principle Elements of Initial Costs are Labor, Material, and Overhead

- **Long-Term Use:** Reliability
  - Probability that a device will function under stated conditions for a stated measure of usage or time
    - Common metric: Mean Time Between Failure (MTBF)

- **Sustainability:**
  - Life-cycle Assessment (LCA): Understand, analyze and document full range of environment effects of a product:
  - Considers design, manufacture, transport, sale, use, and disposal
GROUP ACTIVITY

Come up with 3 possible designs for a water bottle and pick the best one
TODAY’S SPEAKER

LAURIE YOLER