Digital biomimetics
...on the fingers of one hand

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Solving problems the technological way

Vincent et al. (2006) RSJ Interface 3: 471-482
Solving problems the biological way

Vincent et al. (2006) RSJ Interface 3: 471-482
Ashby’s Materials Selection Charts
(http://www-materials.eng.cam.ac.uk/mpsite/interactive_charts/)

Material Property Requirements

Strength (MPa) vs Density (kg/m³)

- Ceramics
- Composites
- High alloy steels
- Magnesium
- Mild Steel
- Woods and wood products
- Polymers
- Aluminium
- Cast Iron
- Porous ceramics
- Lead
- Gold
- Rubbers
- Porous ceramics
- Foams
- Metals and alloys

Strength in tension/compression typically 10% of compressive strength.

Other materials: strength in tension/compression.
Designing a New Material World

Gregory B. Olson  SCIENCE  VOL 288  12 MAY 2000
A paradigm for Biomimetics

- Engineering is numerical, biology is descriptive
- Meeting at DESIGN - the engine of innovation
- Generate DIGITAL DESIGN to bridge the gap
- ‘Materials are expensive but design is cheap’
The PLAN

Texts inform and expand ontology

Agents interrogate ontology

Biology texts

Engineering ontology

Ontology interrogates text sources

Agents integrate information

Progress to design

Data mining and Translation

Agent-based modelling

Data-driven scripting

Digital fabrication
Problems of information

- Hegel: thesis-antithesis >>> synthesis
- Altshuller: codified Hegel in TRIZ
- Texts must pose and resolve a ‘patent’
- All organisms are living ‘patents’
Problems of information

- Many biology papers describe morphology
- Even more papers more describe processes
- Few papers solve a biological problem
- Ontology codifies BIOLOGY into TRIZ
<table>
<thead>
<tr>
<th>Element</th>
<th>Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weight of moving object</td>
<td>21. Power</td>
</tr>
<tr>
<td>2. Weight of stationary object</td>
<td>22. Waste of energy</td>
</tr>
<tr>
<td>3. Length of moving object</td>
<td>23. Waste of substance</td>
</tr>
<tr>
<td>4. Length of stationary object</td>
<td>24. Loss of information</td>
</tr>
<tr>
<td>5. Area of moving object</td>
<td>25. Waste of time</td>
</tr>
<tr>
<td>7. Volume of moving object</td>
<td>27. Reliability</td>
</tr>
<tr>
<td>8. Volume of stationary object</td>
<td>28. Accuracy of measurement</td>
</tr>
<tr>
<td>10. Force</td>
<td>30. Object affected harmful effects</td>
</tr>
<tr>
<td>11. Tension, pressure</td>
<td>31. Object generated side effects</td>
</tr>
<tr>
<td>12. Shape</td>
<td>32. Manufacturability</td>
</tr>
<tr>
<td>13. Stability of object</td>
<td>33. Convenience of use</td>
</tr>
<tr>
<td>14. Strength</td>
<td>34. Repairability</td>
</tr>
<tr>
<td>15. Duration of action - moving object</td>
<td>35. Adaptability</td>
</tr>
<tr>
<td>17. Temperature</td>
<td>37. Complexity of control</td>
</tr>
<tr>
<td>18. Brightness</td>
<td>38. Level of automation</td>
</tr>
<tr>
<td>19. Use of energy by moving object</td>
<td>39. Productivity</td>
</tr>
<tr>
<td>20. Use of energy by stationary object</td>
<td></td>
</tr>
</tbody>
</table>

These provide thesis & antithesis
TRIZ - The 40 inventive principles

1. Segmentation
2. Extraction
3. Local quality
4. Asymmetry
5. Combination
6. Universality
7. Nested doll
8. Counterweight
9. Prior counter-action
10. Prior action
11. Prior cushioning
12. Equipotentiality
13. Other way around
14. Spheroidality
15. Dynamics
16. Partial or excessive action
17. Another dimension
18. Vibration
19. Periodic action
20. Continuity of useful action
21. Skipping
22. Blessing in disguise
23. Feedback
24. Intermediary
25. Self-service
26. Copying
27. Cheap/short life
28. Mechanical substitution
29. Pneumatics and hydraulics
30. Flexible shells/thin films
31. Porous/cellular materials
32. Colour change
33. Homogeneity
34. Discarding and recovering
35. Parameter change
36. Phase transition
37. Thermal expansion
38. Strong oxidant
39. Inert atmosphere
40. Composite material

These are other people’s solutions
<table>
<thead>
<tr>
<th>Worsening Feature</th>
<th>Improving Feature</th>
</tr>
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<tbody>
<tr>
<td>Weight of Moving Object</td>
<td>Weight of Stationary Object</td>
</tr>
<tr>
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<td>Area of Moving Object</td>
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</tr>
<tr>
<td>Volume of Moving Object</td>
<td>Volume of Stationary Object</td>
</tr>
<tr>
<td>Speed</td>
<td>Force (Intensity)</td>
</tr>
<tr>
<td>Pressure</td>
<td>Stability of the Object's Composition</td>
</tr>
<tr>
<td>Shape</td>
<td>Strength</td>
</tr>
<tr>
<td>Duration of Action of Moving Object</td>
<td>Duration of Stationary of Moving Obj.</td>
</tr>
<tr>
<td>Temperature</td>
<td>Illumination Intensity</td>
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<td>Use of Energy by Moving Object</td>
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<td>Loss of Information</td>
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<tr>
<td>Loss of Time</td>
<td>Quality of Substance / Matter</td>
</tr>
<tr>
<td>Reliability</td>
<td>Measurement Accuracy</td>
</tr>
<tr>
<td>Manufacturing Precision</td>
<td>Object-Affected Harmful Factors</td>
</tr>
<tr>
<td>Object-Generated Harmful Factors</td>
<td>Ease of Manufacture</td>
</tr>
<tr>
<td>Ease of Operation</td>
<td>Adaptability or Versatility</td>
</tr>
<tr>
<td>Ease of Repair</td>
<td>Device Complexity</td>
</tr>
<tr>
<td>Difficulty of Detecting and Measuring</td>
<td>Extent of Automation</td>
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<td>Productivity</td>
<td>Weight of Stationary Object</td>
</tr>
</tbody>
</table>
Ontology

“The nature of being”
Load-compression curves of *S. officinalis* phragmacone, wet and dry, showing different types of fracture behavior.
Diagram of a biostructure with labels:
- Lamellar types
- Postero-dorsal
- Intercameral
- Antero-lateral

Key measurements:
- 100 µm
- a, b, h, t
Development of a digital framework for the computation of complex material and morphological behavior of biological and technological systems

Sean Ahlquist a,c,* , Tim Kampowski b , Omid Oliyan Torghabehi a , Achim Menges c , Thomas Speck b
Bending spicule and glass

![Graph showing the relationship between True Stress (MPa) and True Strain (mm/mm) for Glass and Spicule materials.](image)
Integrate...

Functions
Elements and components can be squeezed into less space

Materials
Properties and transformations are shared across functions

Structure
Strength and function intertwine and are indistinguishable

Environment
Energy and matter gradients are created and exploited between the inside and outside of the building

Life cycle
Design, construction, habitation and modification become a continuum and cyclical
I narrowed down the options to an alternative that costs too much and another that won't work.

I didn't do any research. It's more of an experience sort of thing.

Next week I plan to think about the option of using technology that isn't yet available.