A photograph of a custom-built robotic arm and a breadboard circuit on a wooden table. The robotic arm is constructed from white wood and features two DC motors at the base, each with a blue gear. A central white panel is mounted on a track system. To the right, a breadboard circuit is visible, containing a microcontroller, various resistors, and jumper wires. The entire setup is placed on a light-colored wooden surface.

## How to make something that makes almost anything: Prototyping

Nadya Peek

February 2015

This class: Design & Prototyping

Technical design, Industrial design, Product design,

User-centered design, Human-centered design, Participatory design,

Looks-like/works-like, Rapid prototyping, Organisational prototyping

How/what/who/where/why machine?



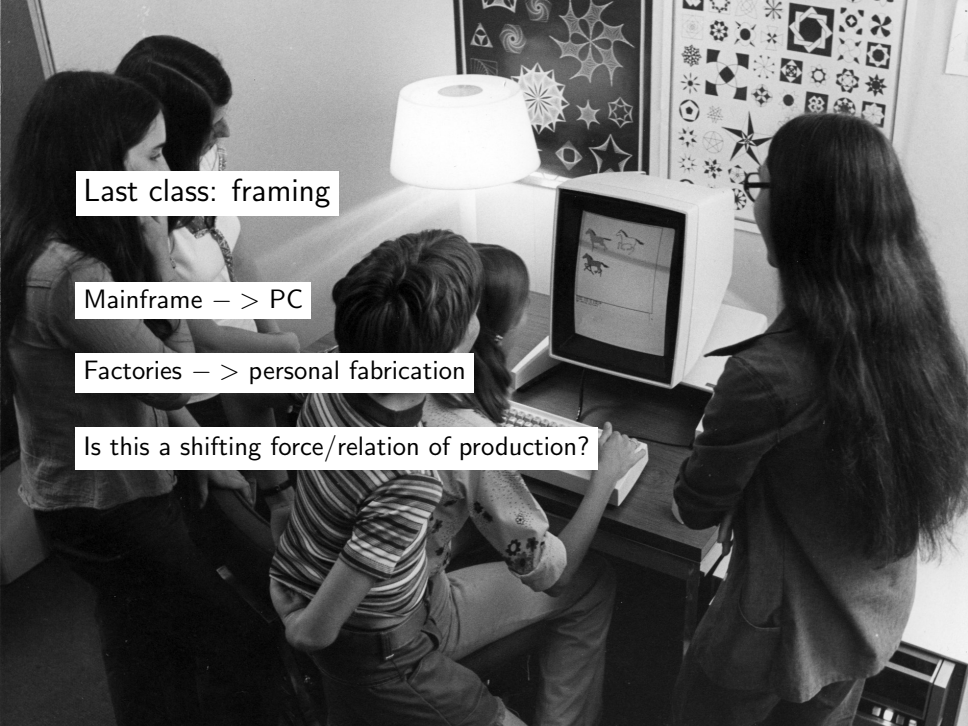
Last class: Marxist technology & rise of CNC

Forces of Production

Relations of Production

PHOTO BY  
WILSON KENT

(B.586)



Last class: framing

Mainframe — > PC

Factories — > personal fabrication

Is this a shifting force/relation of production?

Last class: where are we now?

Forces of Production

Factory – > desktop

Relations of Production

Mainframe – > personal

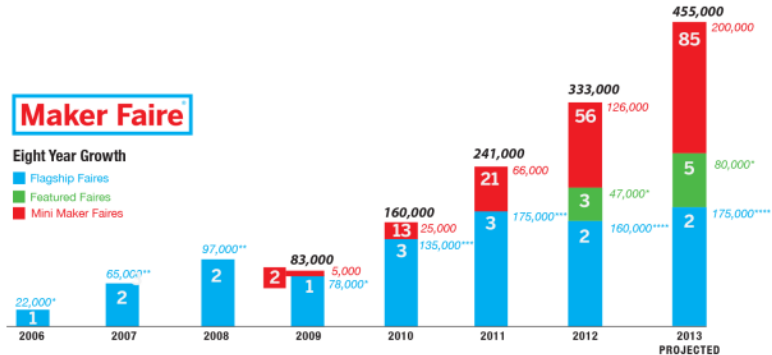
False Consciousness?



# Maker Faire®

## Eight Year Growth

- Flagship Faires
- Featured Faires
- Mini Maker Faires



\* Bay Area Faire only

\*\* Bay Area, Austin

\*\*\* Bay Area, Detroit, New York

\*\*\*\* Bay Area, New York

\*Detroit, Kansas City, Tokyo

\*\*Detroit, Kansas City, Tokyo, UK, Rome

Readings: Transforming society by transforming technology:  
the science and politics of participatory design,

P. Asaro, *Accting., Mgmt. & Info. Tech.* 10 (2000) 257-290

JAD & socio-technical systems + collective resources – >

Participatory design

Users, designers, *and* technology factor into technological development

*"participatory design methods can be a highly successful way to  
build technological systems because it integrates an assessment  
of material, practical and political consequences of a system in  
a single dialectic of resistance and accommodation"*



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Lucy A. Suchman

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**PLANS AND  
SITUATED  
ACTIONS**

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**The problem of  
human machine  
communication**

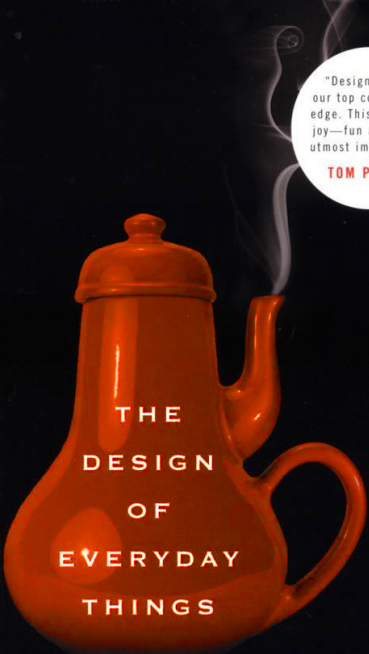
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LEARNING IN DOING: SOCIAL, COGNITIVE, AND COMPUTATIONAL PERSPECTIVES

Who is the user?

Who is the designer?

What is the technology?



"Design may be  
our top competitive  
edge. This book is a  
joy—fun and of the  
utmost importance."

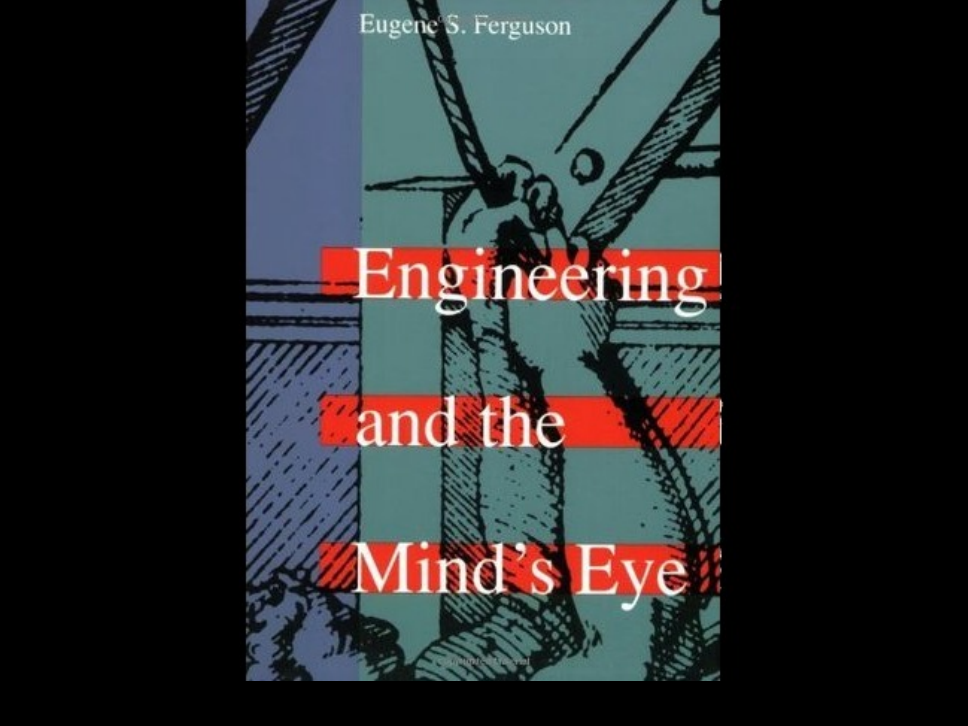
**TOM PETERS**

THE  
DESIGN  
OF  
EVERYDAY  
THINGS

Previously published as *THE PSYCHOLOGY OF EVERYDAY THINGS*

**DONALD A. NORMAN**

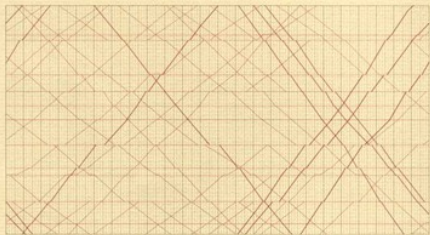
WITH A NEW INTRODUCTION BY THE AUTHOR



Eugene S. Ferguson

Engineering  
and the  
Mind's Eye

Copyrighted material



# The Visual Display of Quantitative Information

EDWARD R. TUFTE



POWER ON

Starchitects and Designers

work where they're paid

Users however...

EMERGENCY STOP



HANDLE JOG

SETUP: JOG

NEW 000001 N00000100

000001 ( LSR HEAD INTAKE2A ) ;  
( SAM RACING ) ;  
( POSTED FOR HAAS ES-5-41 ) ;  
( DATE - 02-07-10 TIME - 09:51 ) ;  
( I1 SFS 3/8 ) ;  
G20 ;  
G00 G17 G40 G90 G94 G98 ;  
G00 G91 G28 Z0 ;  
G00 G91 G28 X0 Y0 A0 ;  
( SFS 3/8 ) ;  
N100 T1 M06 ;  
G00 G90 G94 G54 X-4.1972 Y1.8518 Z21.392  
A17.186 S3500 M03 ;

TOOL INFO

LPS ON	TOOL	COOLANT POSITION	H(LENGTH)	WEAR	GEOMETRY	WEAR
1	SPINDLE	5	-13.9837	0.	0.	0.
2	0	0	0.	0.	0.	0.
3	0	0	0.	0.	0.	0.
4	0	0	0.	0.	0.	0.
5	0	0	0.	0.	0.	0.
6	0	0	0.	0.	0.	0.
7	0	0	0.	0.	0.	0.
8	0	0	0.	0.	0.	0.
9	0	0	0.	0.	0.	0.

TOOL INFO >>

WORK ZERO OFFSET

G CODE	X AXIS	Y AXIS	Z AXIS	A AXIS	B AXIS
G52	0.	0.	0.	0.	0.
G54	-19.8890	-16.2096	0.	0.	29.381
G55	-29.3963	-13.0365	0.	0.	-60.619
G56	0.	0.	0.	0.	58.298
G57	0.	0.	0.	0.	0.
G58	0.	0.	0.	0.	0.
G59	0.	0.	0.	0.	0.
G154 P1	0.	0.	0.	0.	0.
G154 P2	0.	0.	0.	0.	0.
G154 P3	0.	0.	0.	0.	0.

MAIN SPINDLE

STOP

Commanded RPM: 3500  
Actual RPM: 0  
Load: 0

SPINDLE: 100%  
FLD: 00%  
RAPID: 5%

POSITION: (IN) JOG RATE 0.0010

	OPERATOR	WORK	G 54	MACHINE	DIST TO GO
X	-24.2045	-4.3155	-24.2045	0.0000	
Y	-14.4668	1.7428	-14.4668	0.0000	
Z	-14.4077	-14.4077	-14.4077	-0.7340	
A	30.958	30.958	30.958	12.104	
B	49.450	20.069	49.450	-0.012	

TOOL MANAGEMENT

GROUP ID: 0  
DESCRIPTION:  
TOOL IN SPINDLE: 1  
TOOL# EXP LIFE  
0  
0  
0  
0  
0

INPUT: |

AB AXIS UNCLAMPED

RESET

POWER  
ON  
RESET

RECOVER

DISPLAY

PRGMR  
CONVRS

POSIT

OFFSET

CURRNT  
COMD

EDIT

INSERT

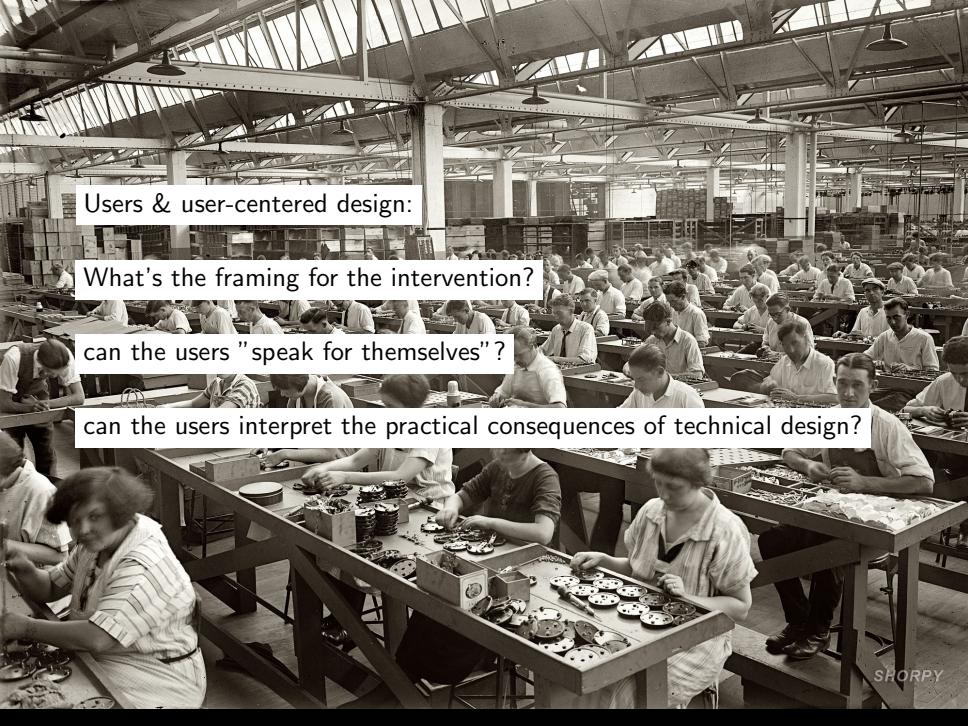
F1

F2

F3

F4

HOT RODDING



Users & user-centered design:

What's the framing for the intervention?

can the users "speak for themselves"?

can the users interpret the practical consequences of technical design?





Users & human-centered design:

can they articulate needs through prototyping?

image: <http://www.ideo.org/stories/the-art-of-rapid-learning>



## Design methodology as a product



## Rapid Prototyping

Build your prototypes quickly, share them immediately, keep learning.

STATS <http://www.designkit.org/>

Suggested time

120 Minutes

**Level of Difficulty**

Hard

**Materials Needed**

Pens, paper, supplies

**Participants**

Design team

Rapid Prototyping is an incredibly effective way to make ideas and to quickly get key feedback from the people you're designing only to convey an idea—not to be perfect—you can quickly move through a variety of iterations, building on what you've learned from the people you're designing for. Rapid Prototyping makes sure that you're building only enough to test your idea, and that you're right back in there making it better once you've gotten the feedback you need.

**STEPS**

01 | Once you've Determined What to Prototype, the time has come to build it.

02 | You can make any number of types of prototypes: Storyboards, Role Plays, models, mock-ups.

PROCESS PHASE



POWER ON POWER OFF

EMERGENCY STOP



HANDLE JOG

SETUP: JOG

NEW 000001 N00000100

000001 ( LSR HEAD INTAKE2A ) ;  
( SAM RACING ) ;  
( POSTED FOR HAAS ES-5-41 ) ;  
( DATE - 02-07-10 TIME - 09:51 ) ;  
( 11 | SFS 3/8 ) ;  
G20 ;  
G00 G17 G40 G90 G94 G98 ;  
G00 G91 G28 Z0. ;  
G00 G91 G28 X0. Y0. A0. ;  
( SFS 3/8 ) ;  
N100 T1 M06 ;  
G00 G90 G94 G54 X-4.1972 Y1.8518 B21.392  
A17.186 S3500 M03 ;  
M11 ;  
M13 ;  
G187 P2 E0.025 ;  
G43 H01 Z4.4025 ;  
Z0.5025 ;  
G01 Z0.4025 F21. ;

TOOL INFO

LPS ON	TOOL	COOLANT POSITION	H(LENGTH)	WEAR	GEOMETRY	WEAR	D(CDIA)
1	SPINDLE	5	-13.9837	0.	0.	0.	0.
2	0	0	0.	0.	0.	0.	0.
3	0	0	0.	0.	0.	0.	0.
4	0	0	0.	0.	0.	0.	0.
5	0	0	0.	0.	0.	0.	0.
6	0	0	0.	0.	0.	0.	0.
7	0	0	0.	0.	0.	0.	0.
8	0	0	0.	0.	0.	0.	0.
9	0	0	0.	0.	0.	0.	0.

WORK ZERO OFFSET

G CODE	X AXIS	Y AXIS	Z AXIS	A AXIS	B AXIS
G52	0.	0.	0.	0.	0.
G53	0.	0.	0.	0.	29.381
G54	0.	0.	0.	0.	-60.619
G55	0.	0.	0.	0.	58.298
G56	0.	0.	0.	0.	0.
G57	0.	0.	0.	0.	0.
G58	0.	0.	0.	0.	0.
G59	0.	0.	0.	0.	0.
G154 P1	0.	0.	0.	0.	0.
G154 P2	0.	0.	0.	0.	0.
G154 P3	0.	0.	0.	0.	0.

MAIN SPINDLE

STOP

Commanded RPM: 3500  
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Z	-14.4077	-14.4077	-14.4077	-0.7340	
A	30.958	30.958	30.958	12.104	
B	49.450	20.069	49.450	-0.012	

TOOL MANAGEMENT

GROUP ID: 0  
DESCRIPTION:  
TOOL IN SPINDLE: 1  
TOOL# EXP LIFE  
0  
0  
0  
0  
0  
0

INPUT: |

AB AXIS UNCLAMPED

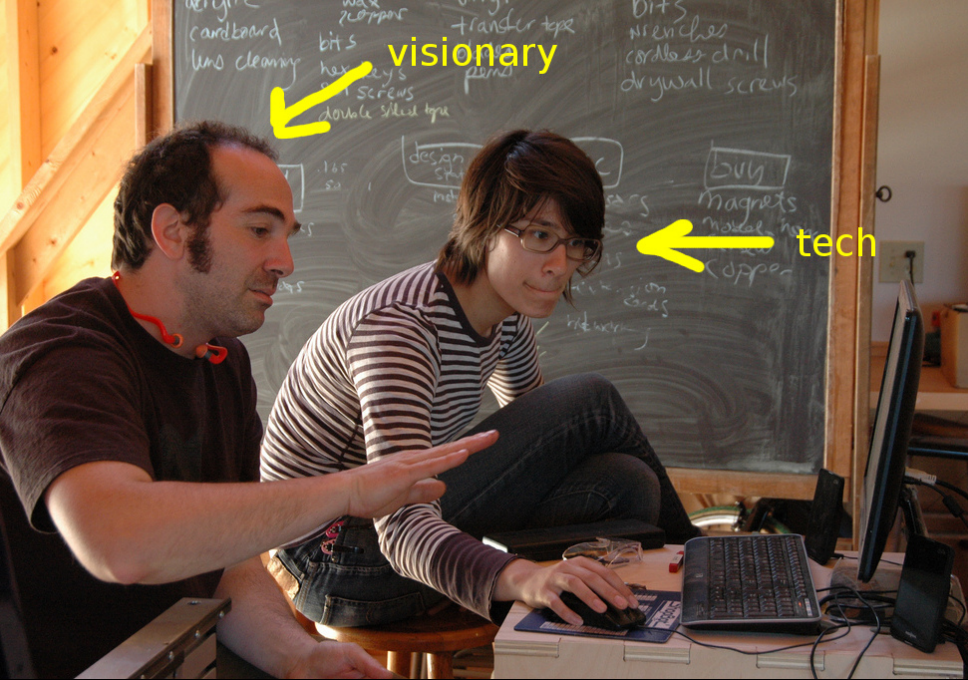
What are the limitations of the user as the designer?





Can users "speak for themselves"? "disrupt"?

see also <http://www.newyorker.com/magazine/2014/06/23/the-disruption-machine>



visionary

tech

You are the designer here.

# Materials and Design

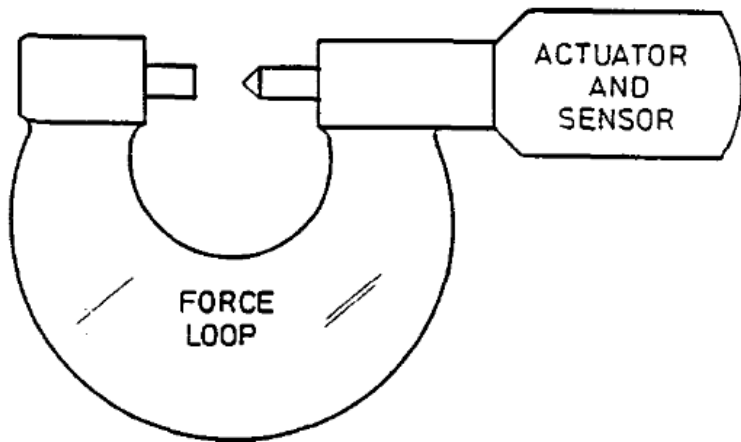
The Art and Science of Material Selection in Product Design

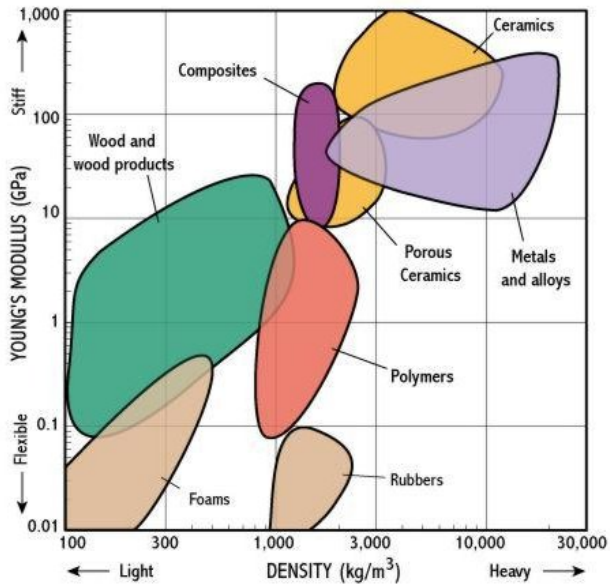
An example from the readings:



**Second Edition**

Mike Ashby and Kara Johnson







## Technical Design

### 100,000 materials

Create limits for mechanical, thermal, and other technical attributes:

### 10-50 materials

Model technical performance and evaluate results:

### 5-10 materials

Create working prototypes, virtual and real, based on a detailed CAD database:

### 1 or 2 materials

Limited understanding of material options

Increasing knowledge of possible materialization of the product

Final selection of material(s) and manufacturing process(es)

## Industrial Design

### 100,000 materials

Outline desired aesthetics, behavior, perception and association:

### 10-50 materials

Explore sample collections, looking at analogous products and experiences:

### 5-10 materials

Create surface prototypes by 3D visualization in a digital file:

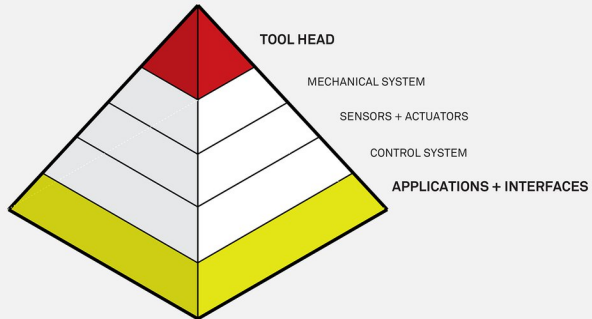
### 1 or 2 materials

But actually, Ashby & Cebon are proposing to "replace" the designer with an interactive software tool.

Where does that leave you as the designer?

What are the aspects you need to synthesise?

## MACHINE MODULARITY



Readings: Gestural Design, a treatise

I. Moyer, 2013

Universal principle of matched impedance

Effort allocation and asymptotic design

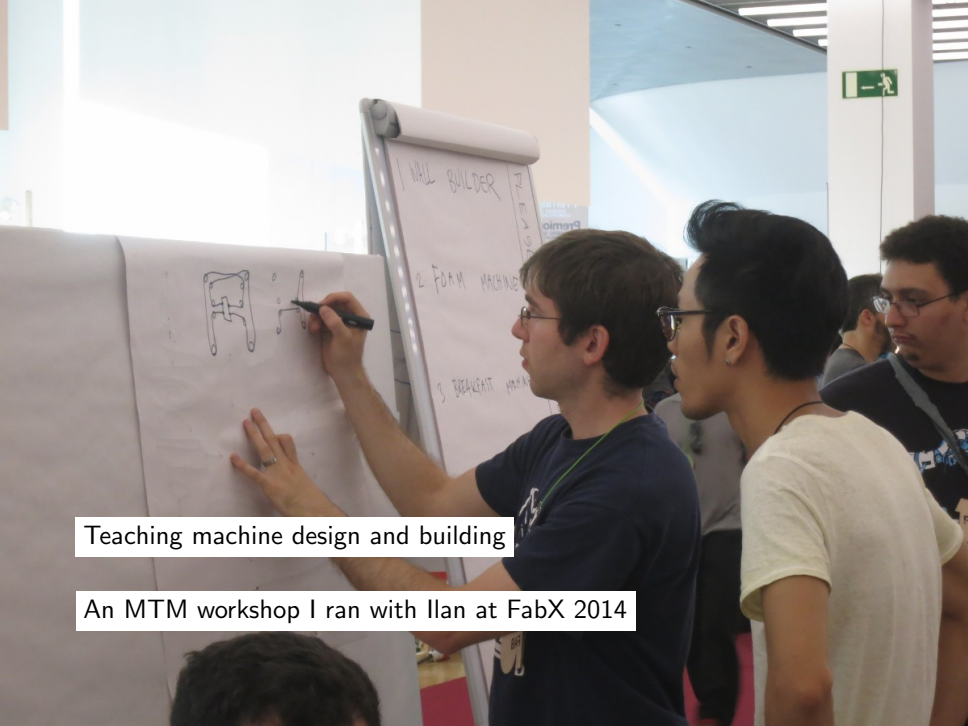
Evolution, intelligent design, and prototyping

Tolerance and precision, satisficing and maximizing

Gestural design

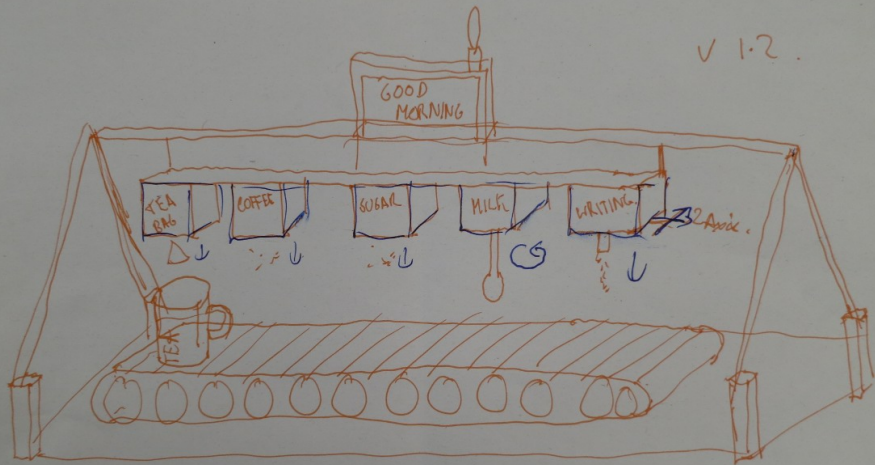
*"The tools of the future will facilitate gestural design. We will have tools which are more tightly coupled to our computers, and we will have computers which are more tightly coupled to our tools. The act of design should be synchronous with fabrication. Serendipity must once again reclaim its throne."*

- Gestural Design, a treatise, I. Moyer, 2013



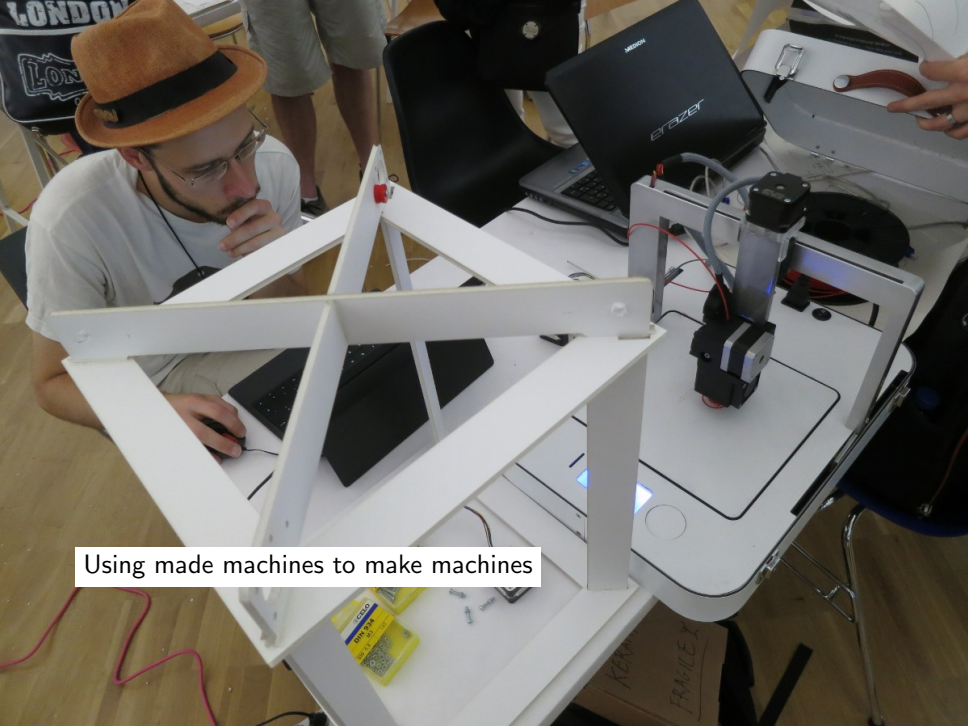
Teaching machine design and building

An MTM workshop I ran with Ilan at FabX 2014



Ideas for machines

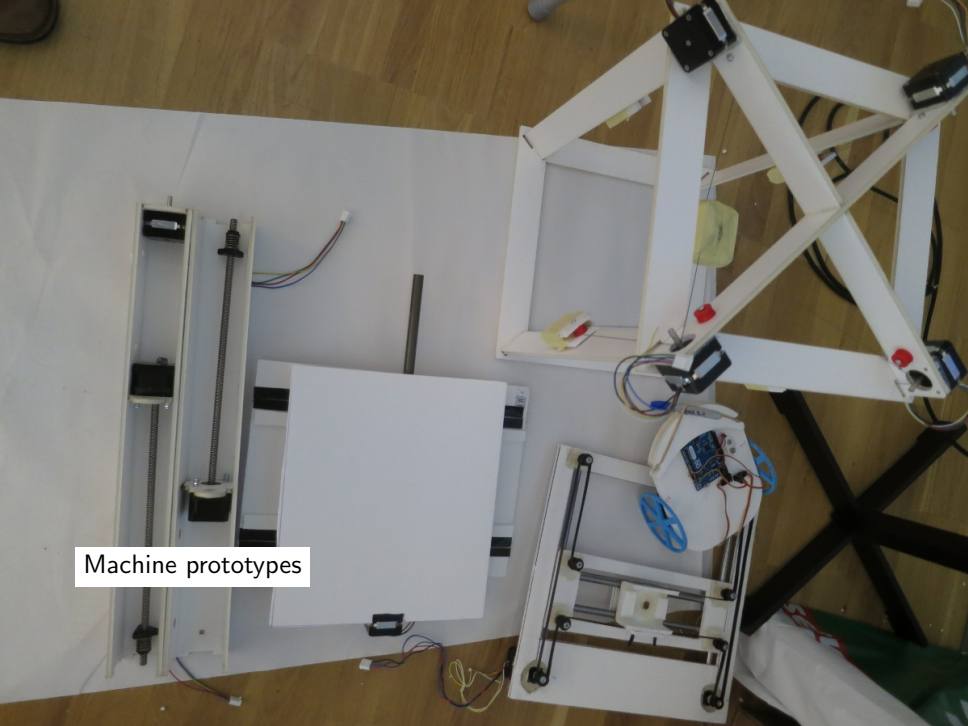
YOR: AXIS  
→



Using made machines to make machines



Machine prototypes





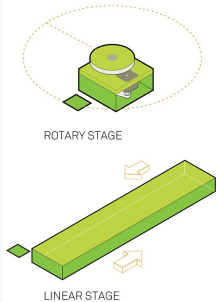
Machine testing

Can it be even faster?

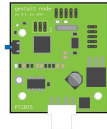


MTM week in HTMAA, with James Coleman, 2014

## MODULAR MACHINE PARTS



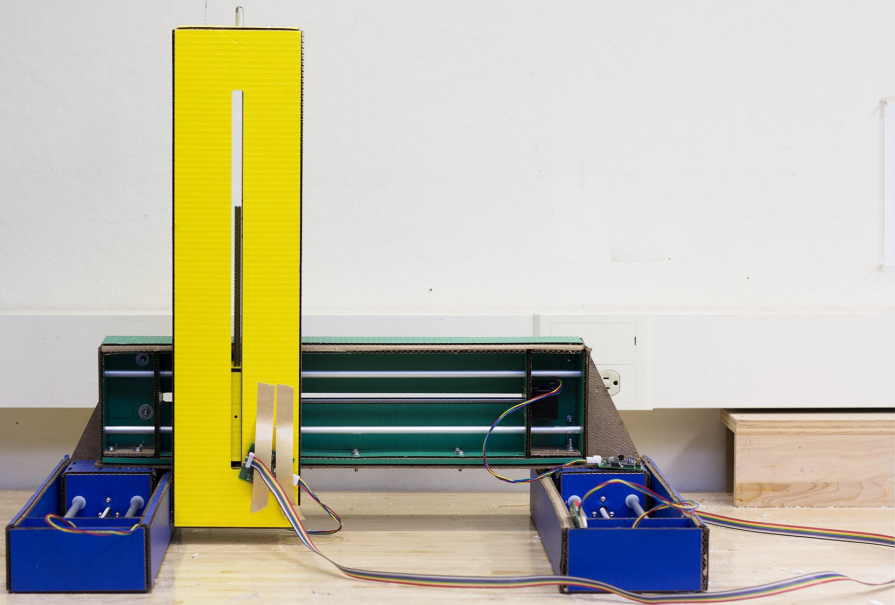
**GESTALT NODE**



## GESTALT FRAMEWORK

```

1  # Import the pandas module
2  import pandas as pd
3
4  # Create a dictionary of data
5  data = {
6      'name': ['John', 'Jane', 'Bob', 'Alice', 'Charlie', 'David', 'Eve', 'Frank', 'Grace', 'Henry'],
7      'age': [25, 30, 35, 40, 45, 50, 55, 60, 65, 70],
8      'gender': ['Male', 'Female', 'Male', 'Female', 'Male', 'Male', 'Female', 'Male', 'Female', 'Male'],
9      'height': [1.75, 1.65, 1.85, 1.70, 1.90, 1.80, 1.75, 1.95, 1.85, 1.70],
10     'weight': [70, 60, 80, 75, 90, 85, 70, 95, 80, 75],
11     'blood_pressure': [120, 110, 130, 125, 140, 135, 120, 145, 130, 125],
12     'heart_rate': [70, 65, 75, 70, 80, 75, 65, 85, 70, 70],
13     'cholesterol': [200, 180, 220, 210, 230, 220, 200, 240, 210, 200],
14     'glucose': [100, 90, 110, 105, 120, 115, 100, 125, 110, 105],
15     'smoking': [0, 1, 0, 1, 0, 0, 1, 0, 1, 0],
16     'alcohol': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
17     'exercise': [0, 1, 0, 1, 0, 1, 0, 0, 1, 0],
18     'stress': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
19     'sleep': [0, 1, 0, 1, 0, 1, 0, 0, 1, 0],
20     'diet': [0, 1, 0, 1, 0, 1, 0, 0, 1, 0],
21     'family_history': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
22     'genetics': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
23     'environment': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
24     'lifestyle': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
25     'social': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
26     'cultural': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
27     'economic': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
28     'political': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
29     'religious': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
30     'ethnicity': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
31     'race': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
32     'gender': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
33     'age': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
34     'height': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
35     'weight': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
36     'blood_pressure': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
37     'heart_rate': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
38     'cholesterol': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
39     'glucose': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
40     'smoking': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
41     'alcohol': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
42     'exercise': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
43     'stress': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
44     'sleep': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
45     'diet': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
46     'family_history': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
47     'genetics': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
48     'environment': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
49     'lifestyle': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
50     'social': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
51     'cultural': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
52     'economic': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
53     'political': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
54     'religious': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
55     'ethnicity': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
56     'race': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
57     'gender': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
58     'age': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
59     'height': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
60     'weight': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
61     'blood_pressure': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
62     'heart_rate': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
63     'cholesterol': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
64     'glucose': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
65     'smoking': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
66     'alcohol': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
67     'exercise': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
68     'stress': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
69     'sleep': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
70     'diet': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
71     'family_history': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
72     'genetics': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
73     'environment': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
74     'lifestyle': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
75     'social': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
76     'cultural': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
77     'economic': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
78     'political': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
79     'religious': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
80     'ethnicity': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
81     'race': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
82     'gender': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
83     'age': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
84     'height': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
85     'weight': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
86     'blood_pressure': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
87     'heart_rate': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
88     'cholesterol': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
89     'glucose': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
90     'smoking': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
91     'alcohol': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
92     'exercise': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
93     'stress': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
94     'sleep': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
95     'diet': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
96     'family_history': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
97     'genetics': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
98     'environment': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
99     'lifestyle': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
100    'social': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
101    'cultural': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
102    'economic': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
103    'political': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
104    'religious': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
105    'ethnicity': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
106    'race': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
107    'gender': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
108    'age': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
109    'height': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
110    'weight': [0, 0, 1, 0, 0, 1, 0, 0, 1, 0],
1
```



Modular machines that make: prototyping with axes of motion

Now: prototyping motion systems with foamcore fun

Assignment for next week:

Make a software tool for fabrication (see website)

Next week: materials