# Future Design + Fabrication

Jonathan Bachrach

EECS UC Berkeley

October 22, 2015

# News



- proposals as presentations for tuesday
- alternating weeks of 1-1 and presentations
- thu dec 10th final presentation during rr week
- final project writeups due tue dec 15

# This Time: Future Fabrication



- History
- Alternatives
- Human Assisted
- Robotic Construction
- Digital Materials
- Instructions
- Smart Assembly
- Self Assembly


dna origami = rothemund -> shih et al

# 3D Printing Capturing All Attention



# But What about?



- big/small scales
- practical materials
- novel fabrication techiques
- speed

# History of Digital Fabrication



knitting -> 3d printing

# Knitting – 1000AD



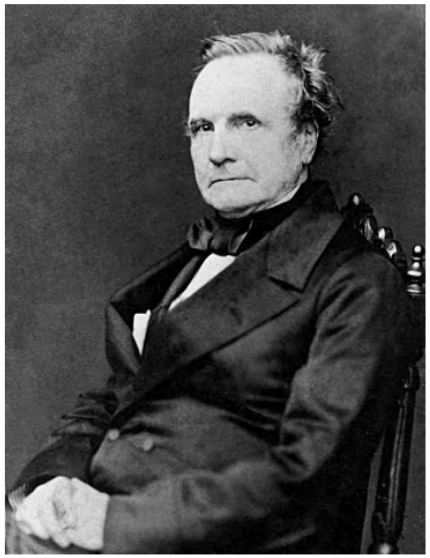
# Punch Card Loom – 1801

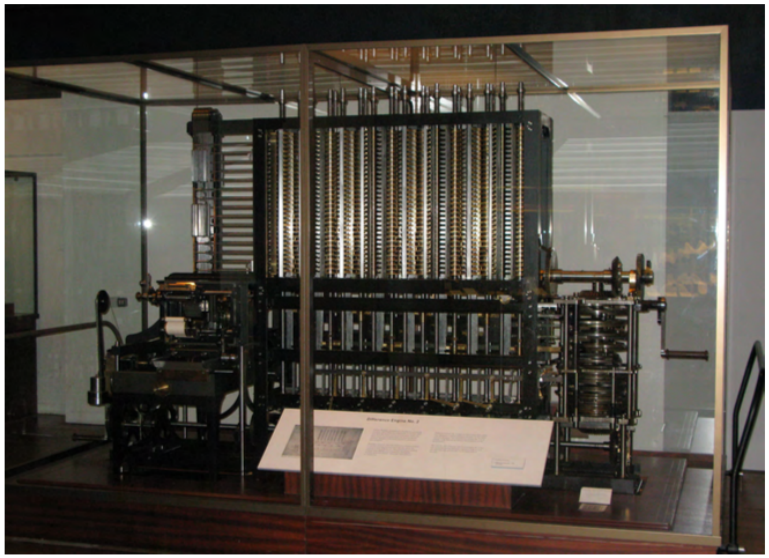



Jacquard

# Weaver – 1820



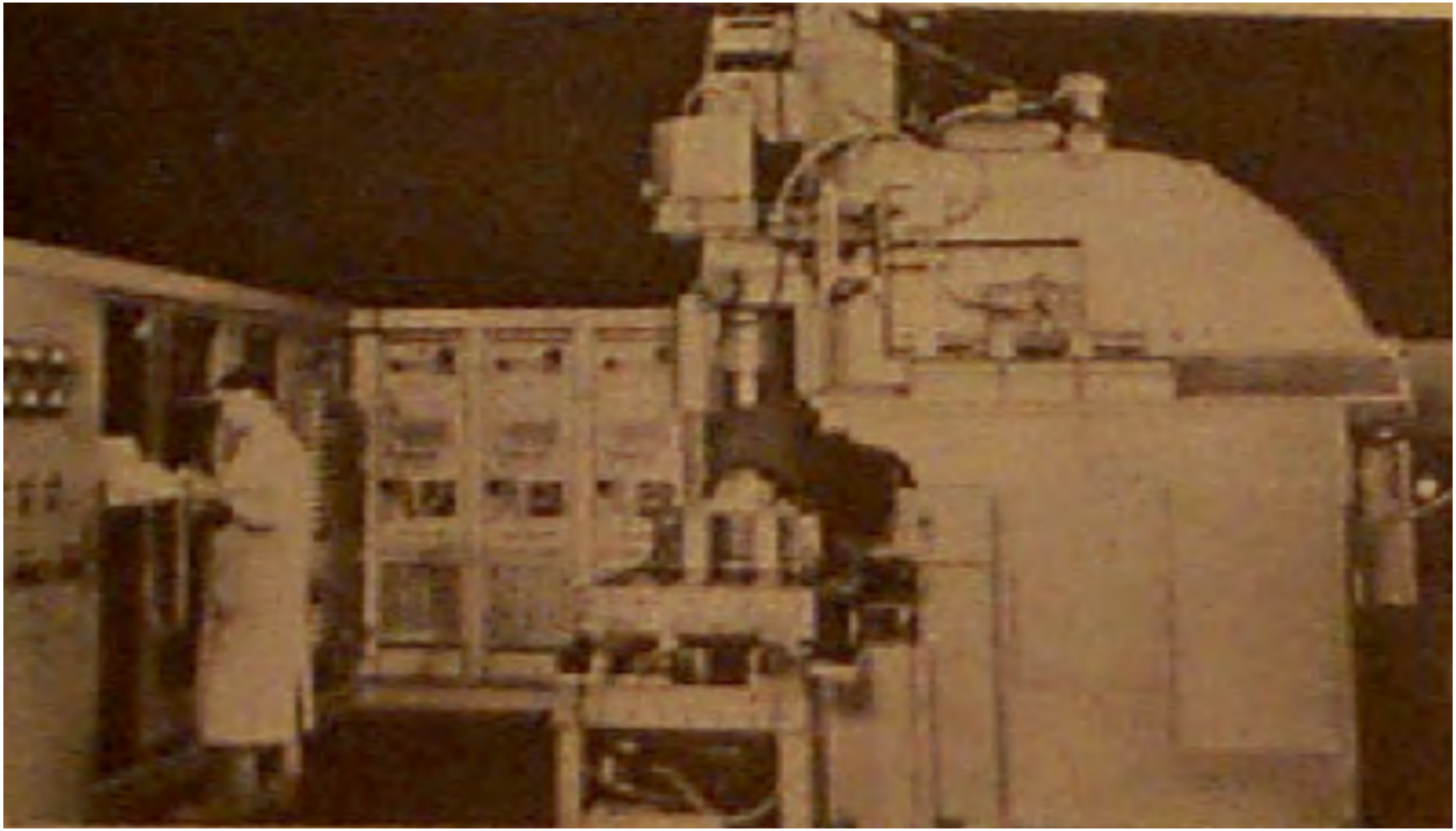




Charles Babbage + Ada Lovelace

# CNC Mill – 1949





John T Parsons + MIT

# 3D Printing – 1984




Charles Hull

# Alternative Machines



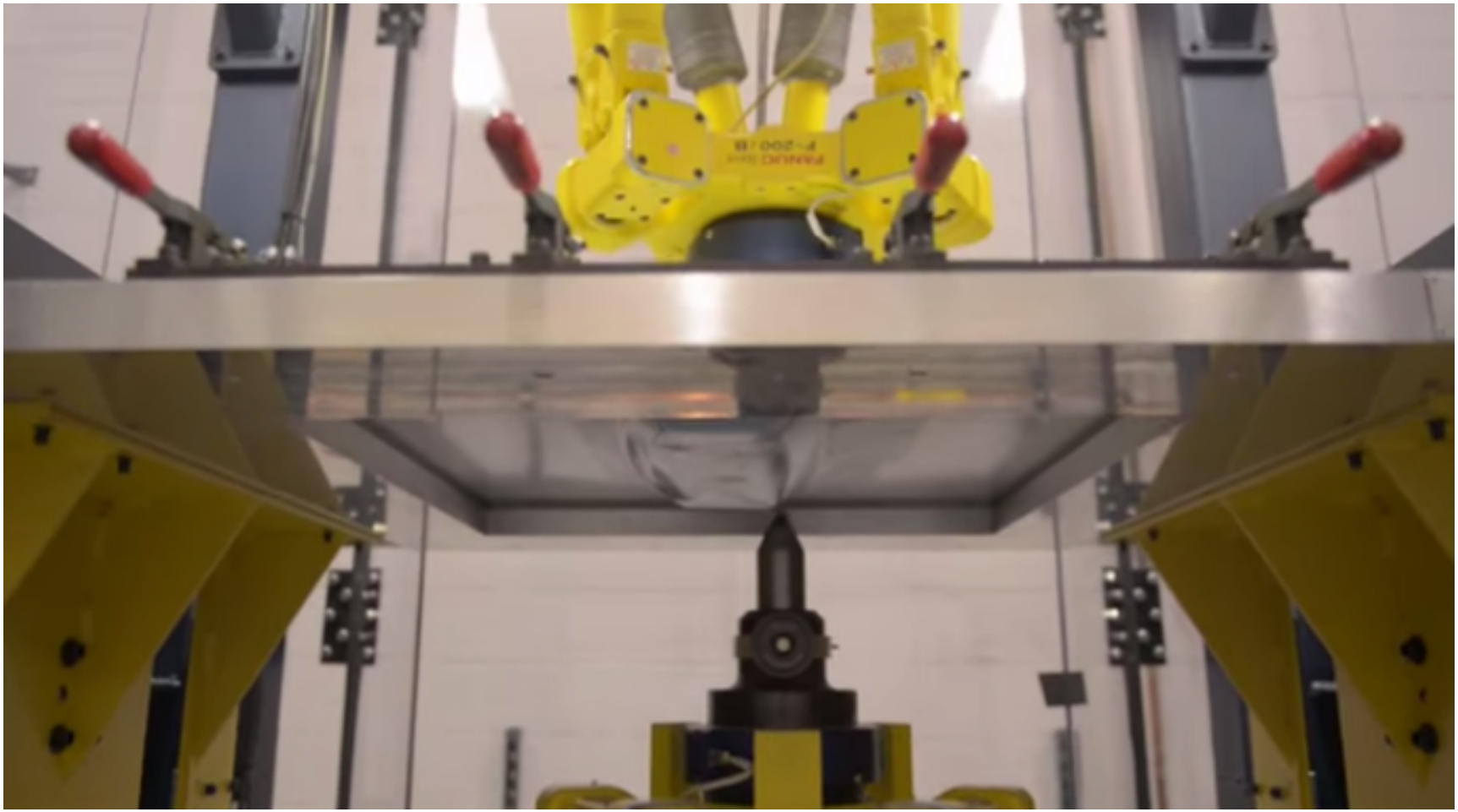
cnc dimensions

- size
- material
- technique
- speed

# DiWire Bender




https://vimeo.com/41425580



https://www.youtube.com/watch?v=Wl5_wUVxRvw&hd=1

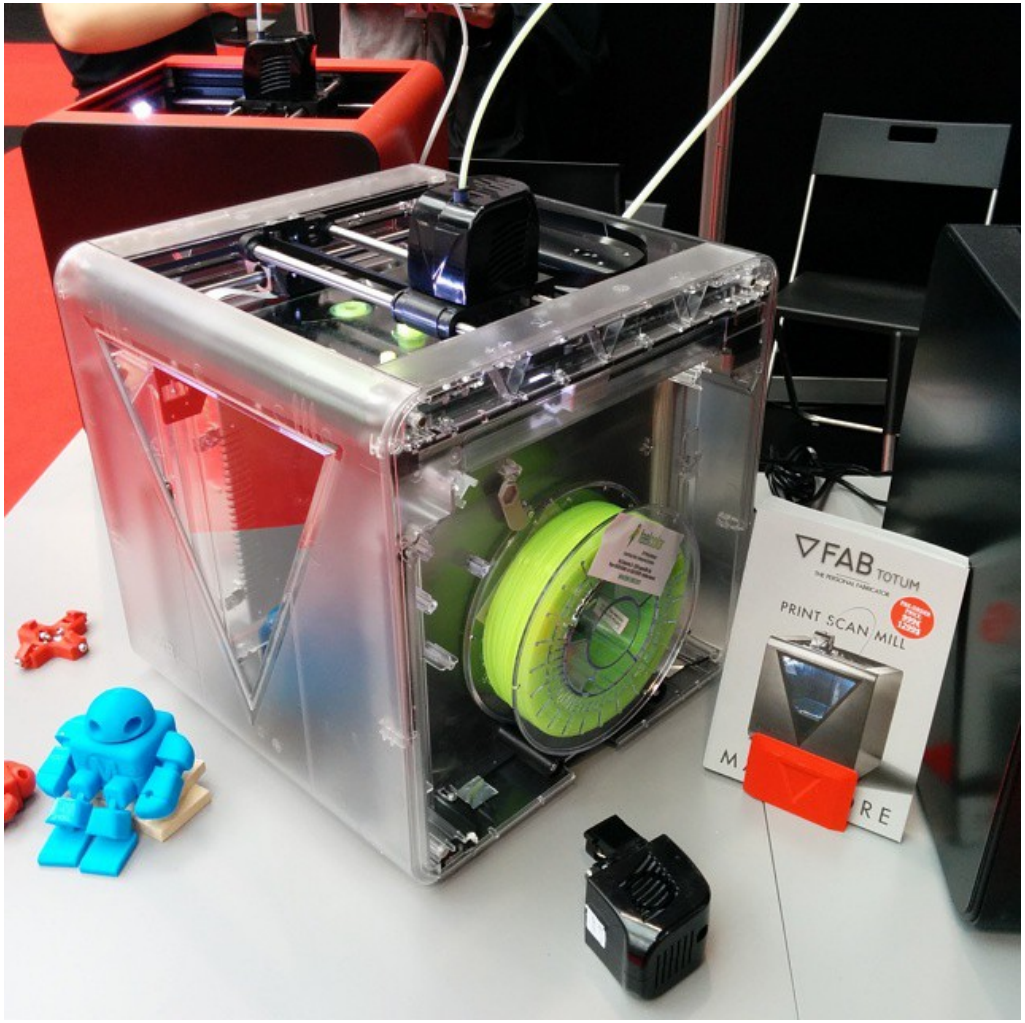
# Web Weaver



http://www.popsci.com/technology/article/2012-04/video-robot-spider-weaves-intricate-web-around-itself

# Print Scan Mill



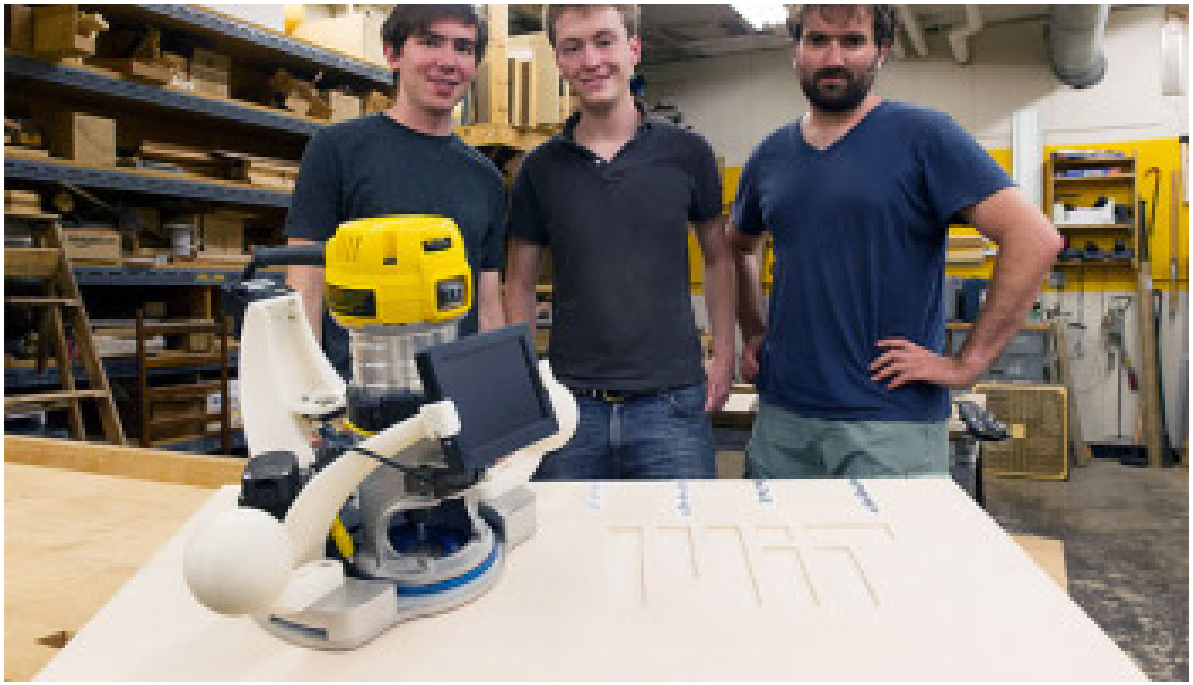



http://www.fabtotum.com/

# Computer Assisted Human Fabrication

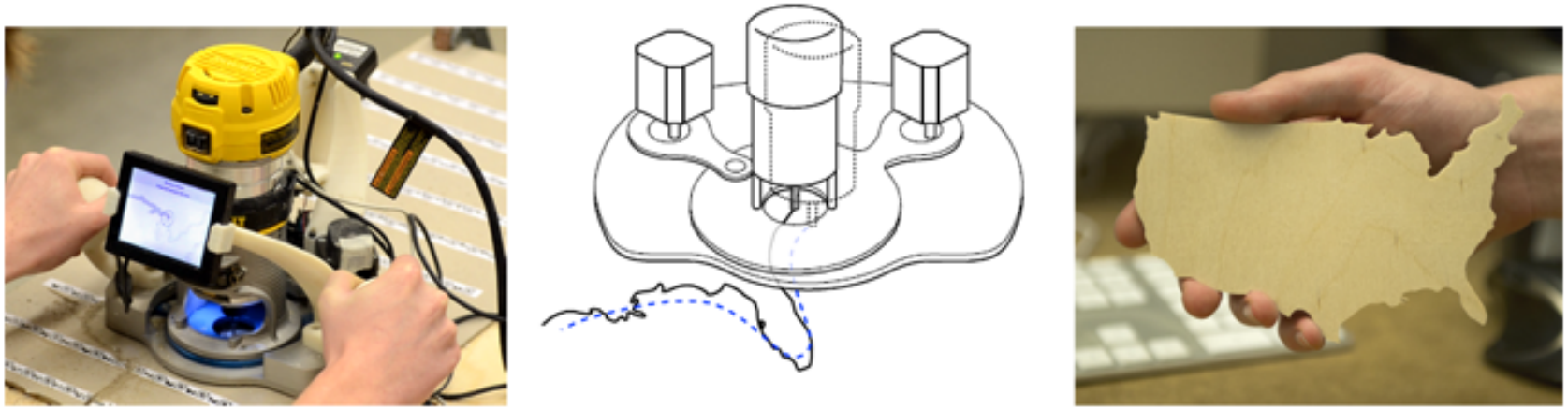


- can we use computers to guide humans to better fabricate?
- lower cost
- leverage skilled workforce
- still do fabrication hard by humans alone



# Position Controlled 2D Tools





(a) (b) (c)

http://www.alecrivers.com/positioncorrectingtools/

# Sculpting By Numbers



(a) Target 3D model

(b) Guidance projected onto material

(c) Sculpted physical replica

http://www.alecrivers.com/sculptingbynumbers/

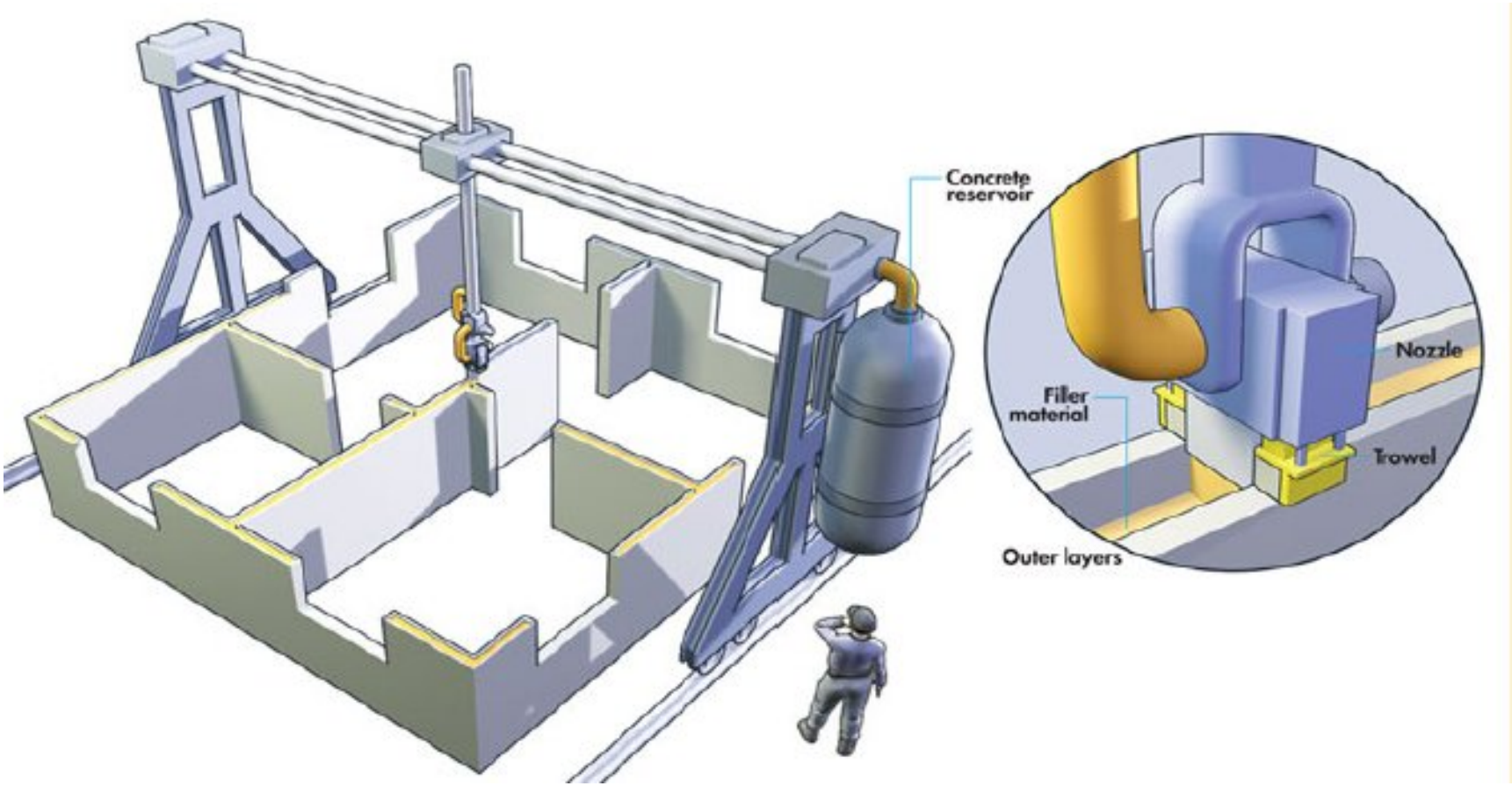
# Robotic Construction



- robots are assembling cars
- what are other possibilities?

# Building Scale Construction

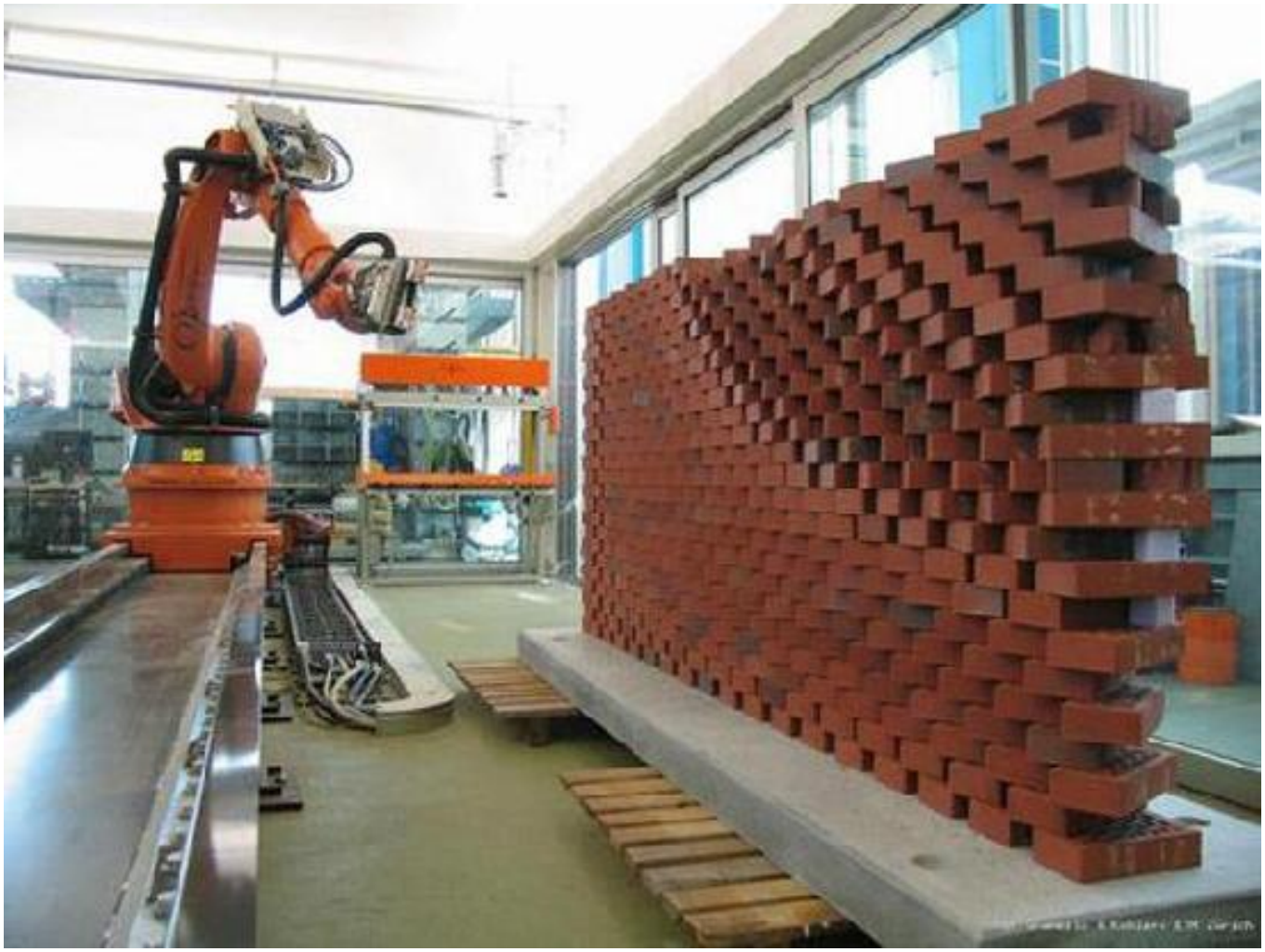





https://www.youtube.com/watch?v=j_qxZPl7SqU

# Brick Laying Robot



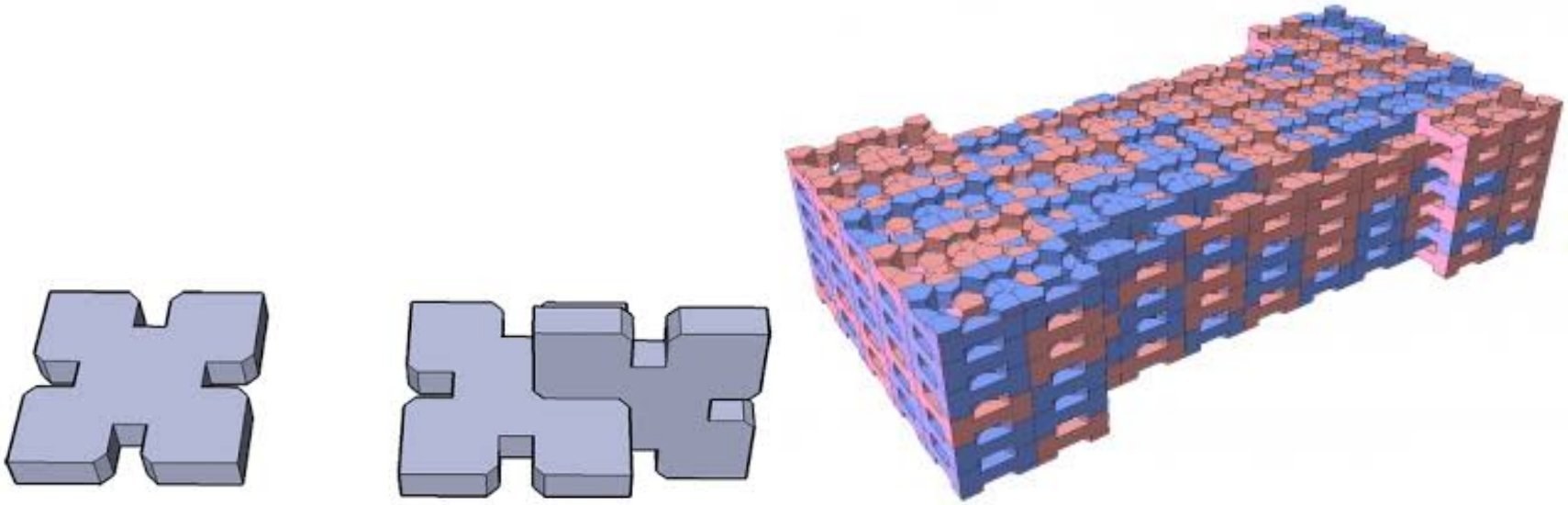


https://www.youtube.com/watch?v=kDW6XCB7HPE

# Digital Materials



- error correction
- reusable



MIT CBA + Cornell

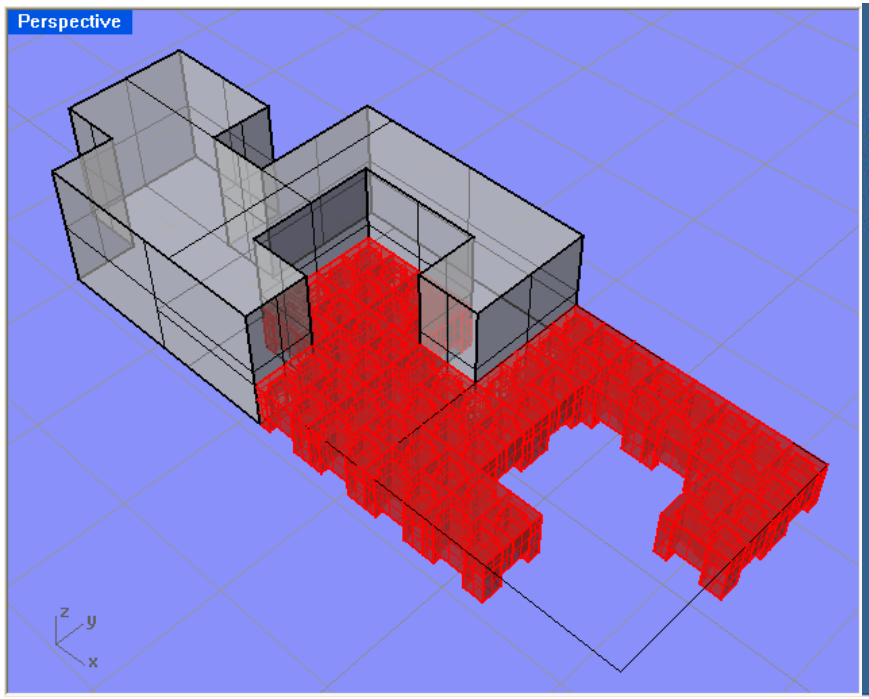
# Digital Material Assembler

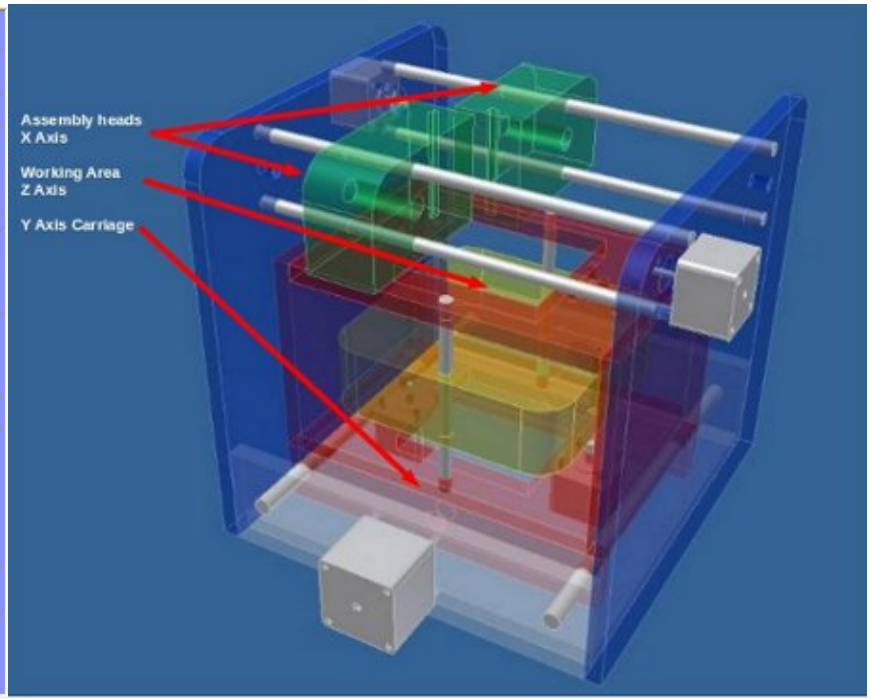


https://www.youtube.com/watch?v=-szjlhVMGh4

# Digital Assembler





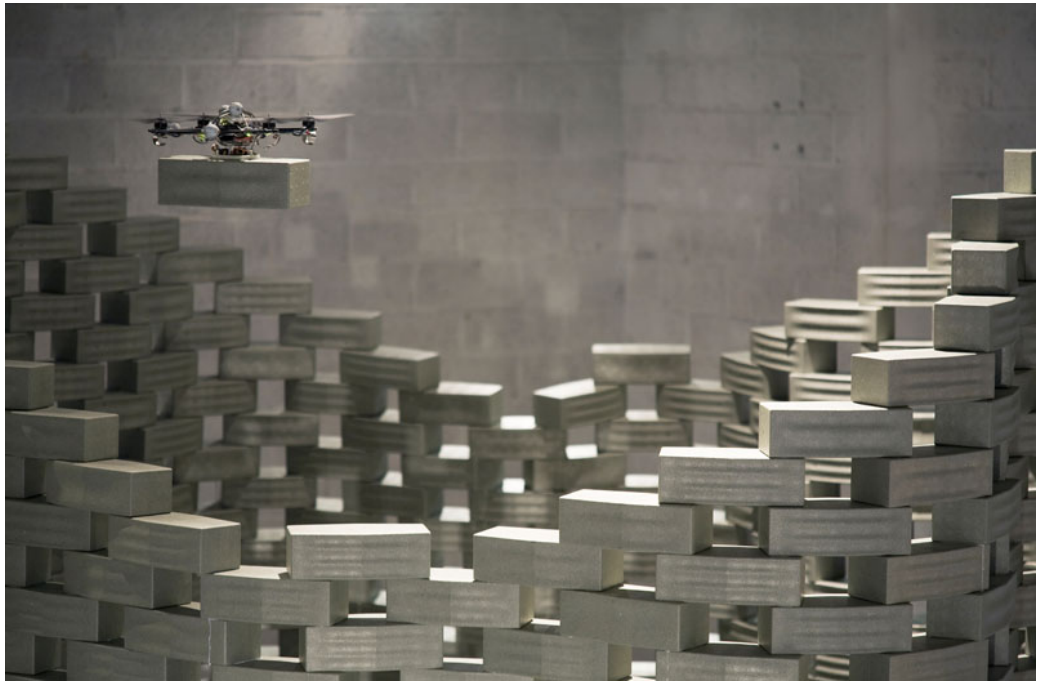




file://users/jrb/jproto/lib/talks/jik/hippo.mov

# Collective Construction



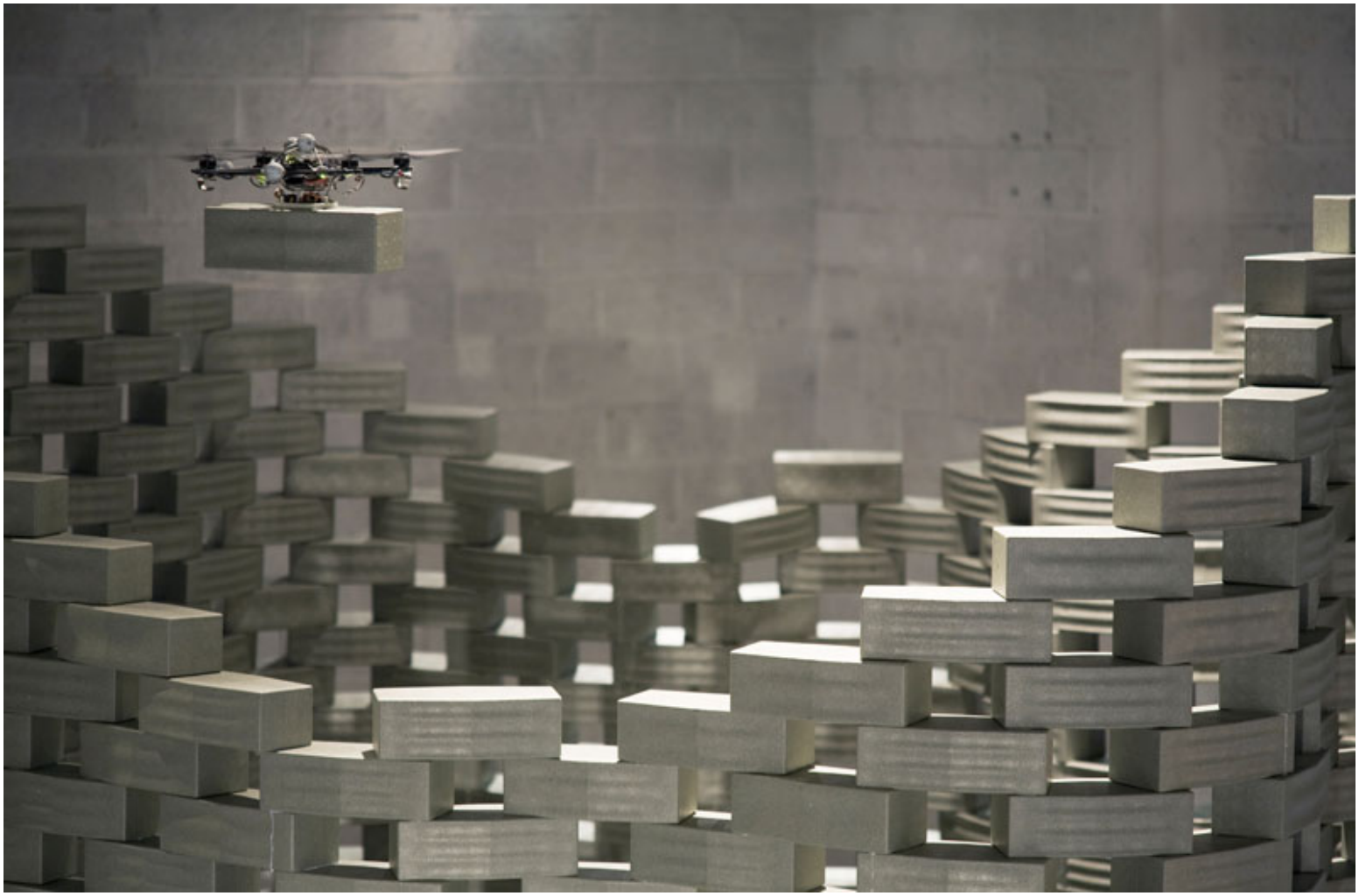
- scale up to use multiple robots
- how to break up construction task
- what are appropriate materials and robots?



ETH

# Flying Brick Layers

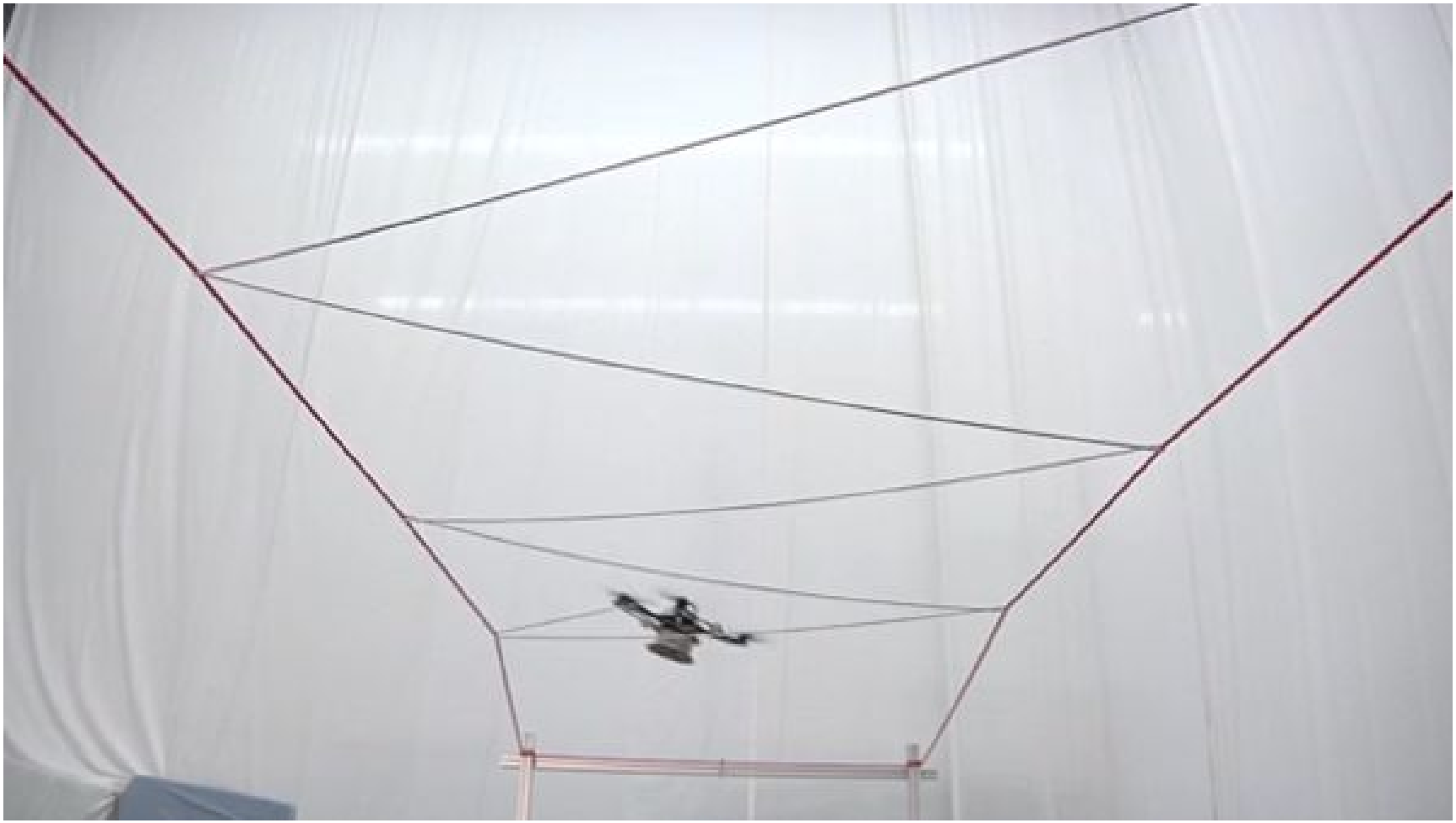




https://www.youtube.com/watch?v=xvN9Ri1GmuY

# Flying Weavers

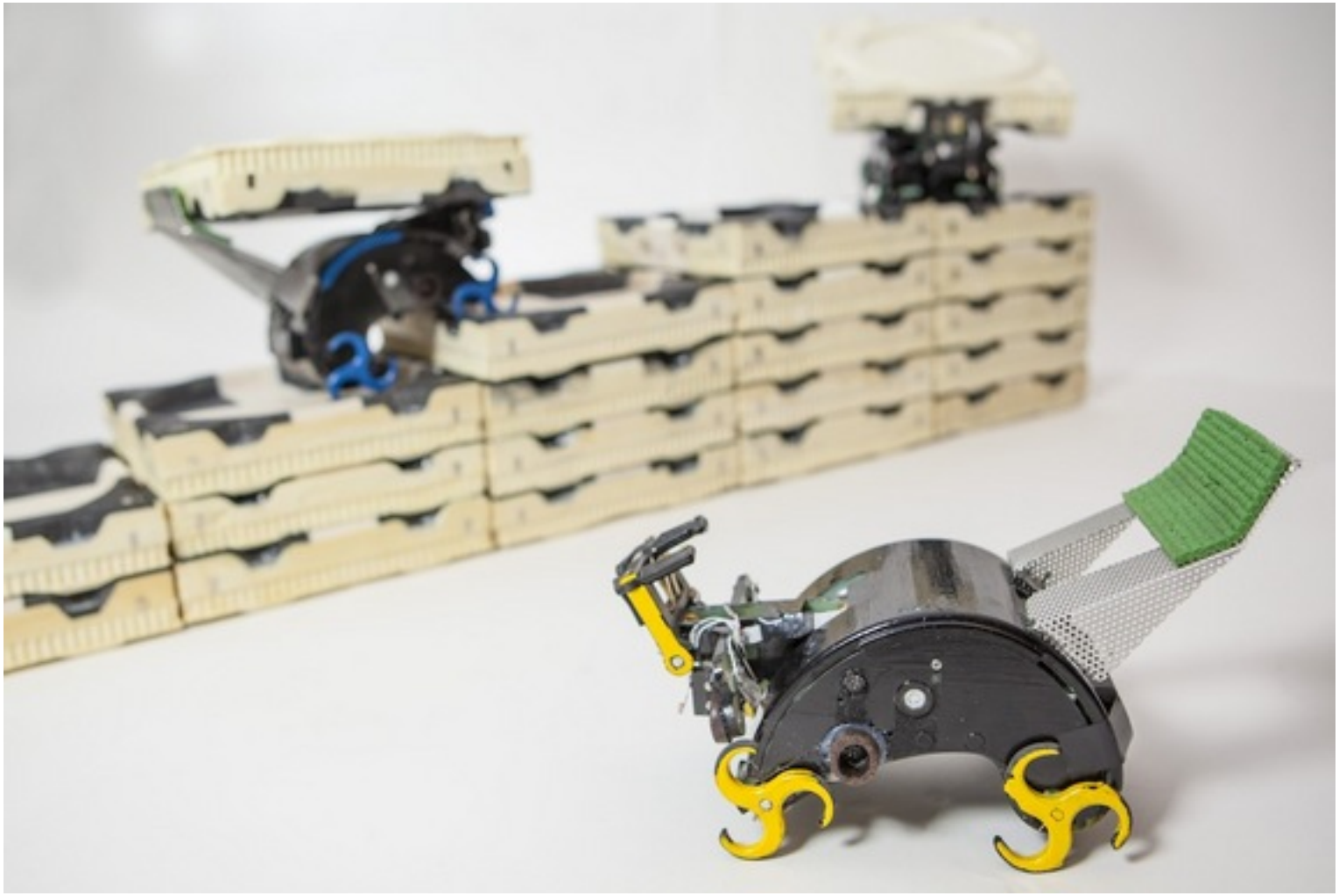




https://www.youtube.com/watch?v=_T0J5PB2av8

# Termite Inspired Construction



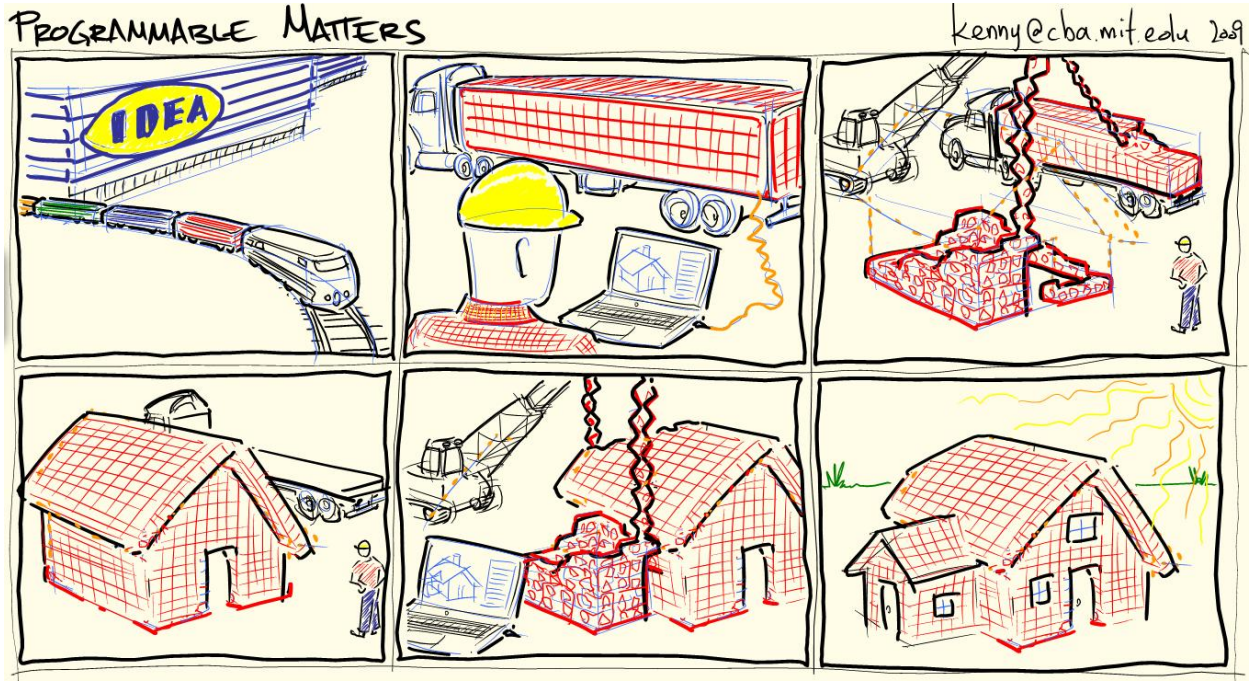


https://www.youtube.com/watch?v=LFwk303p0zY&feature=youtu.be

# Programmable Matter



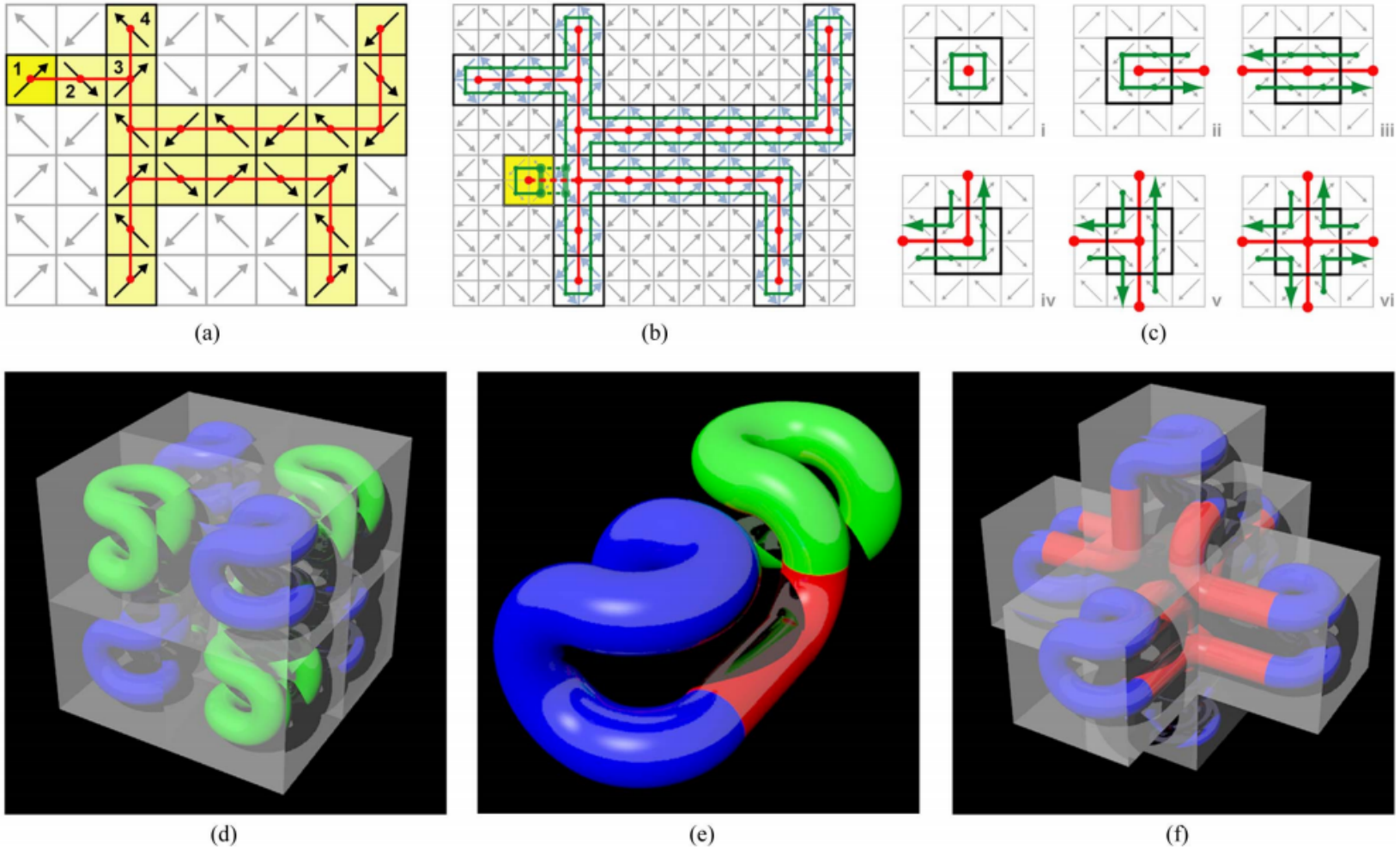
- reconfigure and recycle materials
- what are units?
- is it universal?




bachrach + cheung + griffith + et al

# Mechanical Protein Folding

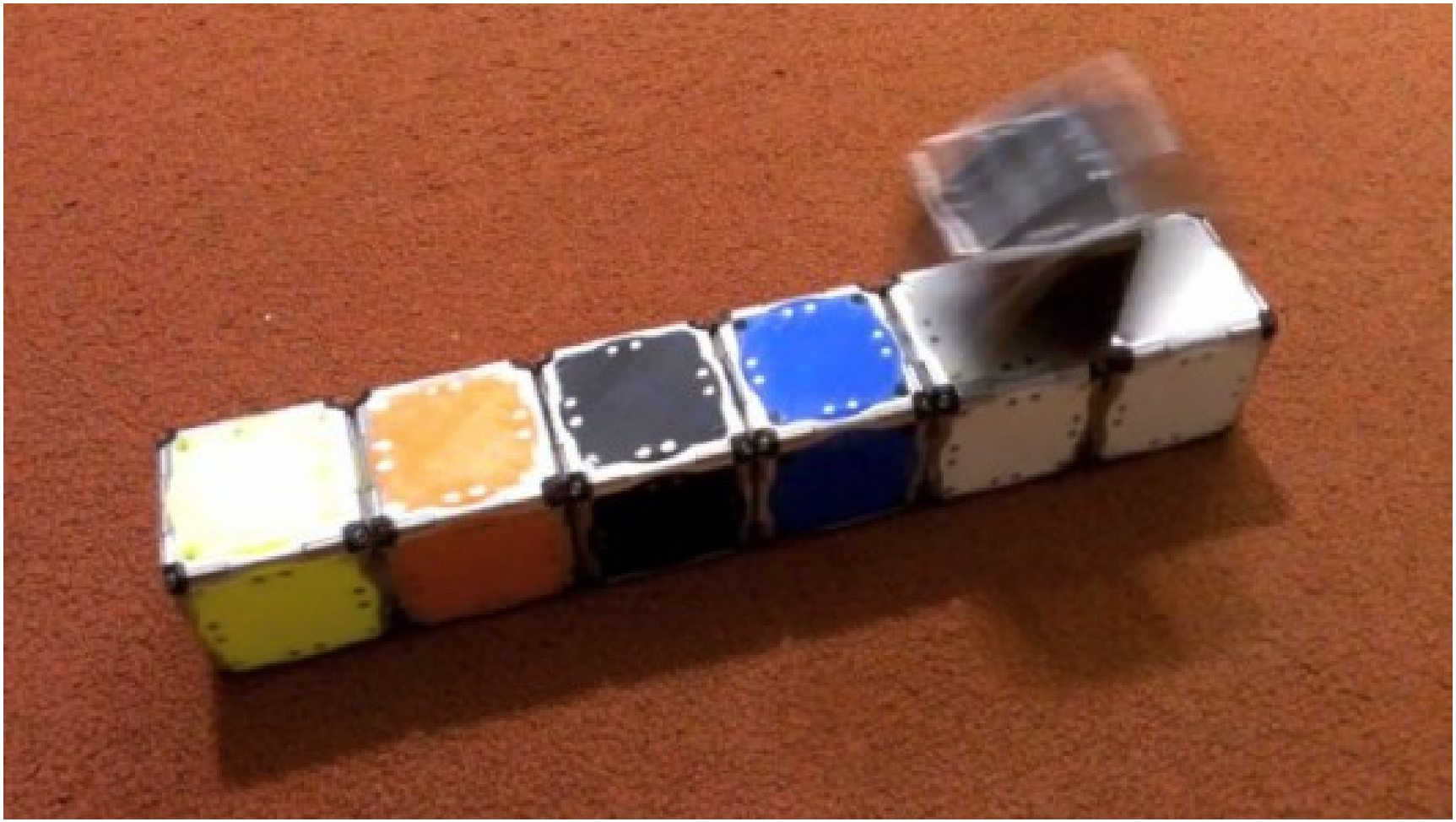





http://www.jbot.org/out/sf-structures.mov

# Robotic Cubes



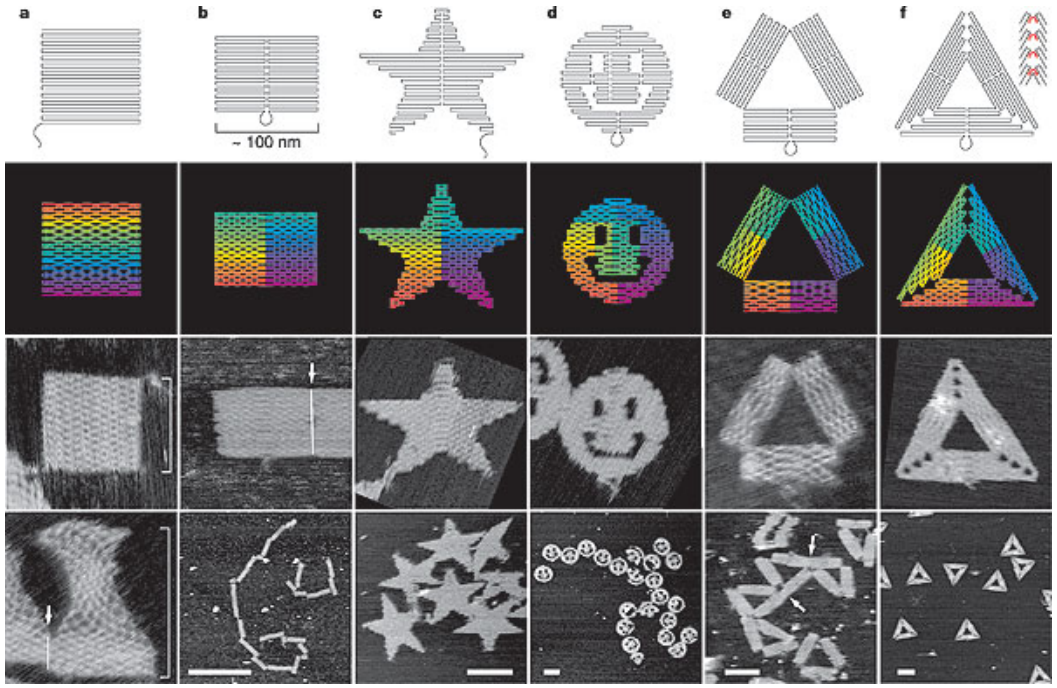


https://www.youtube.com/watch?v=6aZbJS6LZbs

# Self Assembly

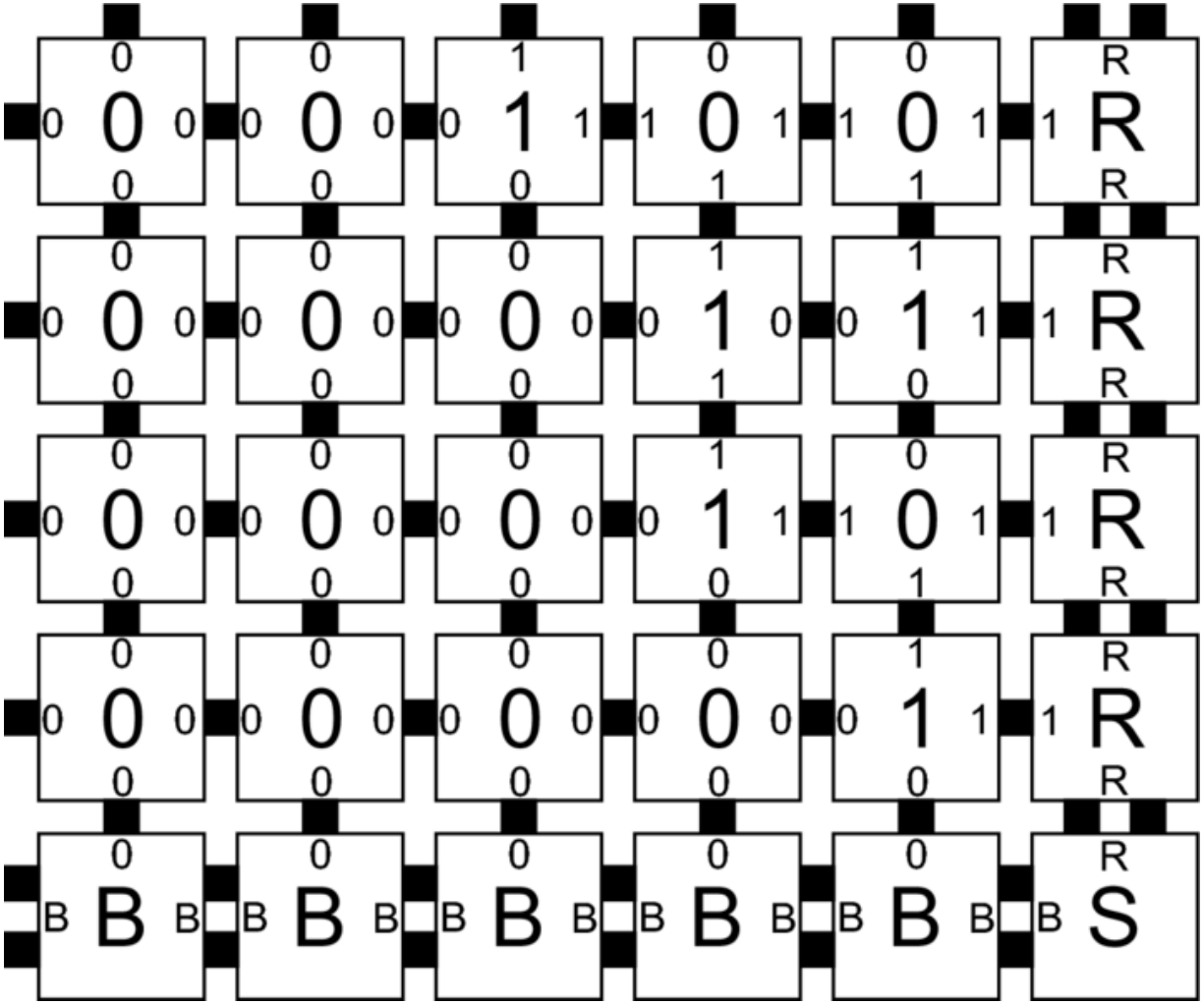


- nature constructs through distributed and collaborative motion
- how do you program it?
- is it universal?
- is it alive?




paul rothemund

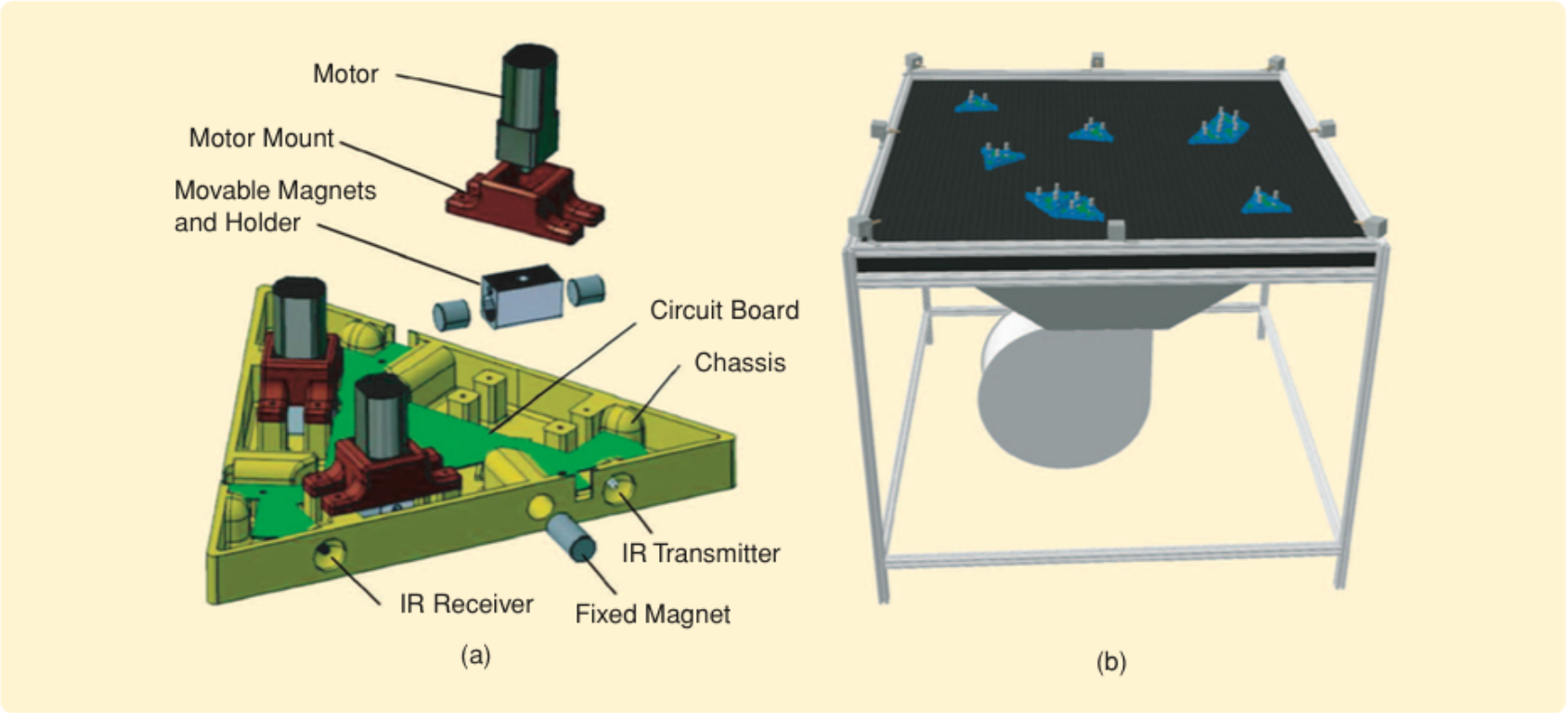
# Tiled Assembly




winfree et al

# Self-Assembly Grammar






klavins et al

# DNA Self Assembly



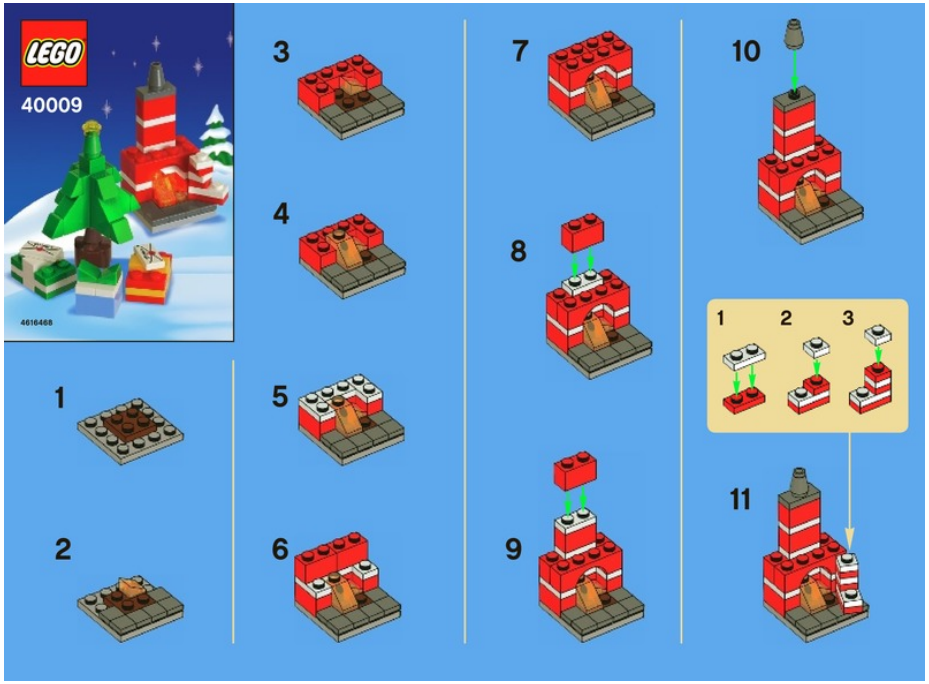

https://www.youtube.com/watch?v=-xv5rHYNXZQ


douglas + shih + ...

# Instructions



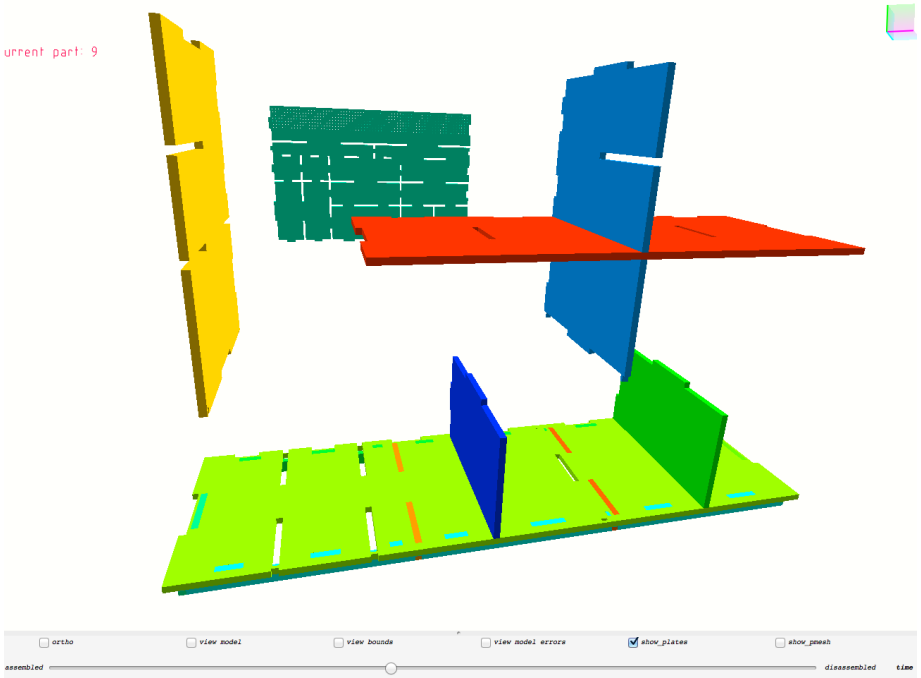
- don't have a robotic assembler
- human is another machine target
- eventually robot will do assembly
- several ways to communicate assembly instructions



# Instruction Information

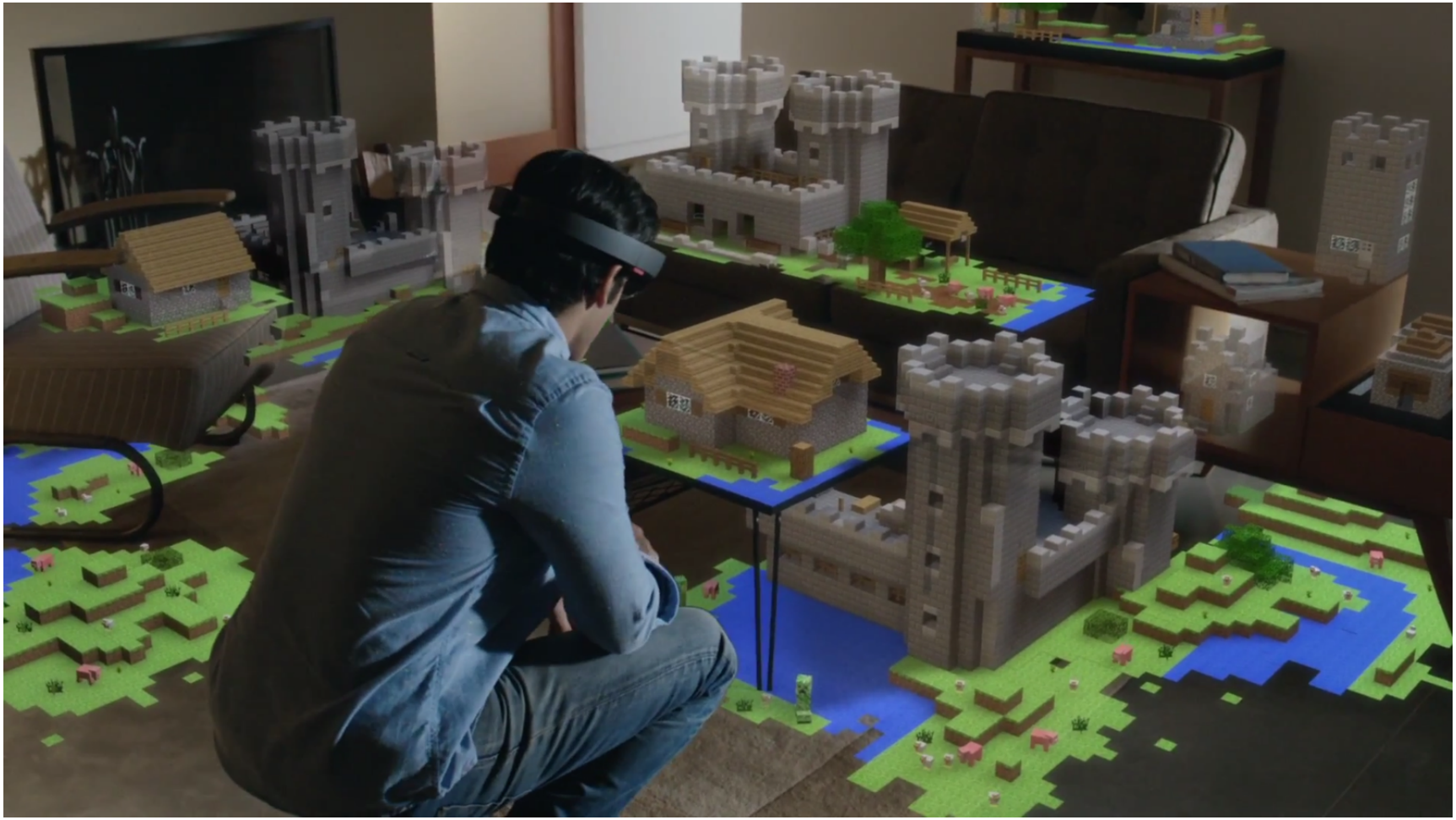


- order of assembly
- topological information
- relative geometric placement including angle and position
- global placement for perspective
- insertion information



# Augmented Reality





https://www.youtube.com/watch?v=aThCr0PsyuA


http://www.jbot.org/out/makani/boyp-720p.mov

# Codee




https://www.youtube.com/watch?v=hGBi5QxP4AU

- IMPACT
- BEING DIGITAL
- BEING SOFTWARE
- BEING SOCIAL
- PROBLEM OR SOLUTION

# Economics and Impact



- 1/4 of economy is in manufacturing
- 3/4 if you include shipping and retail

# Industrial Revolution



- amplify people and make them more productive
- fewer people needed for basic needs like food clothing shelter
- leads to people spending more time on arts, invention, learning, philosophy, politics, creativity
- in short a vast surplus of time
- result richer healthier longer living and more populous

# World is Round Again?



Advantages of cheap labor are disappearing

- closeness to ultimate consumer
- transportation costs
- flexibility, quality, and reliability

# Traditional Manufacturing Bottlenecks



1. popular enough to manufacture
2. popular enough for retailers to carry
3. popular enough for you to find through advertising

- amazon shows that web helps with 2 and 3
- 3d printing helps with lowering costs on 1 and making manufacturing scale-free
- scale-free manufacturing local similar to global – can scale manufacturing
- no cost to complexity and short runs

# Killer App for Digital Fab is Personal Fab



Mass Customization

- make not what you can buy at Walmart but what you can't ***
- power of the unique
- pay more for personalized item and leads to less waste

*** by Neil Gershenfeld in his book Fab

# More Ecological

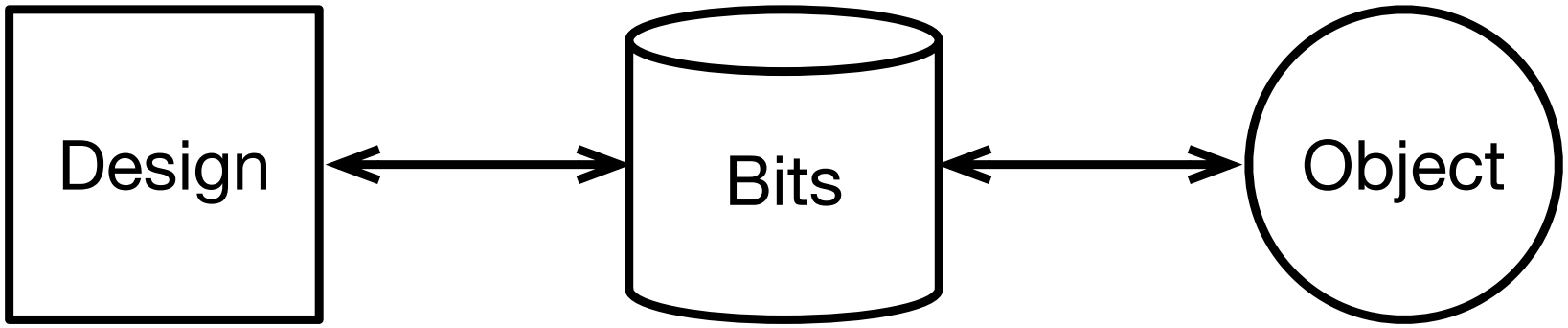


- can reduce shipping because can be made locally
- just in time manufacturing
- only use materials you need
- more personalized and so value it more and will hang onto it longer

# Virtuous Digital Design Loop



- file formats + WWW
- collaboratively created, shared, remixed reimagined, ...
- atoms are the new bits



# Design / Fab -> SW Design



- more abstraction
- promote reuse
- sw generators instead of static one off designs
- decrease design constraints

# Agile Design



- more incremental with stakeholders
- small teams
- simplicity and focus
- steady velocity
- changing requirements so building right thing (vs thing right)
- design rule checking

# Want Smart Scanning



- gives you voxels
- want high level geometric objects
- infer categories and relationships

# Live in Remix Culture



- works well with music + video
- designs need to be more remixable
- need to be more reusable
- need abstraction to be successful

# Network Effects



- making in public
- virtuous cycle <- people see others make and want to make
- only do value add – borrow rest – less infrastructure

# Instructables



- make this more modular and reusable
- more like software – executable
- getting better

# Collaborative Design



- need more tools to design collaboratively
- floobits plugins for editors
- minecraft
- VR design

# Open Source



- give away the bits and sell the atoms
- get more in return than they lose –
  - support, feedback, documentation, marketing, social capital
- cheaper, faster, better research and development
- people can make products themselves but only 0.1% do

# How Computational?



- high level declarative inputs
- learn from example
  - want this and not this but yes that
- learn from big data – all designs
- robotic assembly

# Problem and Solution



- AI and robotics can ultimately do everything better
- so much productivity – people out of jobs
- how to transfer wealth back to people?
- robots are our children

# Heilmeier Questions



- What are you trying to do? Articulate your objectives using absolutely no jargon. What is the problem? Why is it hard?
- How is it done today, and what are the limits of current practice?
- What's new in your approach and why do you think it will be successful?
- Who cares?
- If you're successful, what difference will it make? What impact will success have? How will it be measured?
- What are the risks and the payoffs?
- How much will it cost?
- How long will it take?
- What are the midterm and final "exams" to check for success? How will progress be measured?

# Google Research Proposal Questions



- Clearly Specifies a Problem
- Describes a specific, credible, relevant outcome
- Crisply differentiates the proposed contribution from prior work
- Tells us how the research challenge(s) will be addressed
- Puts the proposed work in context.
- Makes the case to a non-expert.

# Proposal Distillation



- Who? ( team )
- Why? ( motivation and differentiation )
- What? ( clear description of outcome )
- How? ( break it down )
- Successful? ( criteria, objectives )
- When? ( schedule )

# References




- *Coordinating Construction of Truss Structures using Distributed Equal-mass Partitioning* by Yun + Schwager + Rus
- *Self-Reconfiguration Using Directed Growth* by Stoy + Nagpal
- *An Introduction to Tile-Based Self-Assembly* by Patitz
- *Design and Analysis of Digital Materials for Physical 3D Voxel Printing* by Hiller + Lipson
- *Digital Materials for Digital Printing* by Popescu + Mahale + Gershenfeld
- *Rapid prototyping of 3D DNA-origami shapes with caDNAno* by Douglas + Marblestone + Teerapittayanon + Vazquez + Church + Shih
- *Programmable Self-Assembly* by klavins
- *Programmable Assembly With Universally Foldable Strings (Moteins)* by Cheung + Demaine + Bachrach + Griffith
- *Makers: The New Industrial Revolution* by Chris Anderson