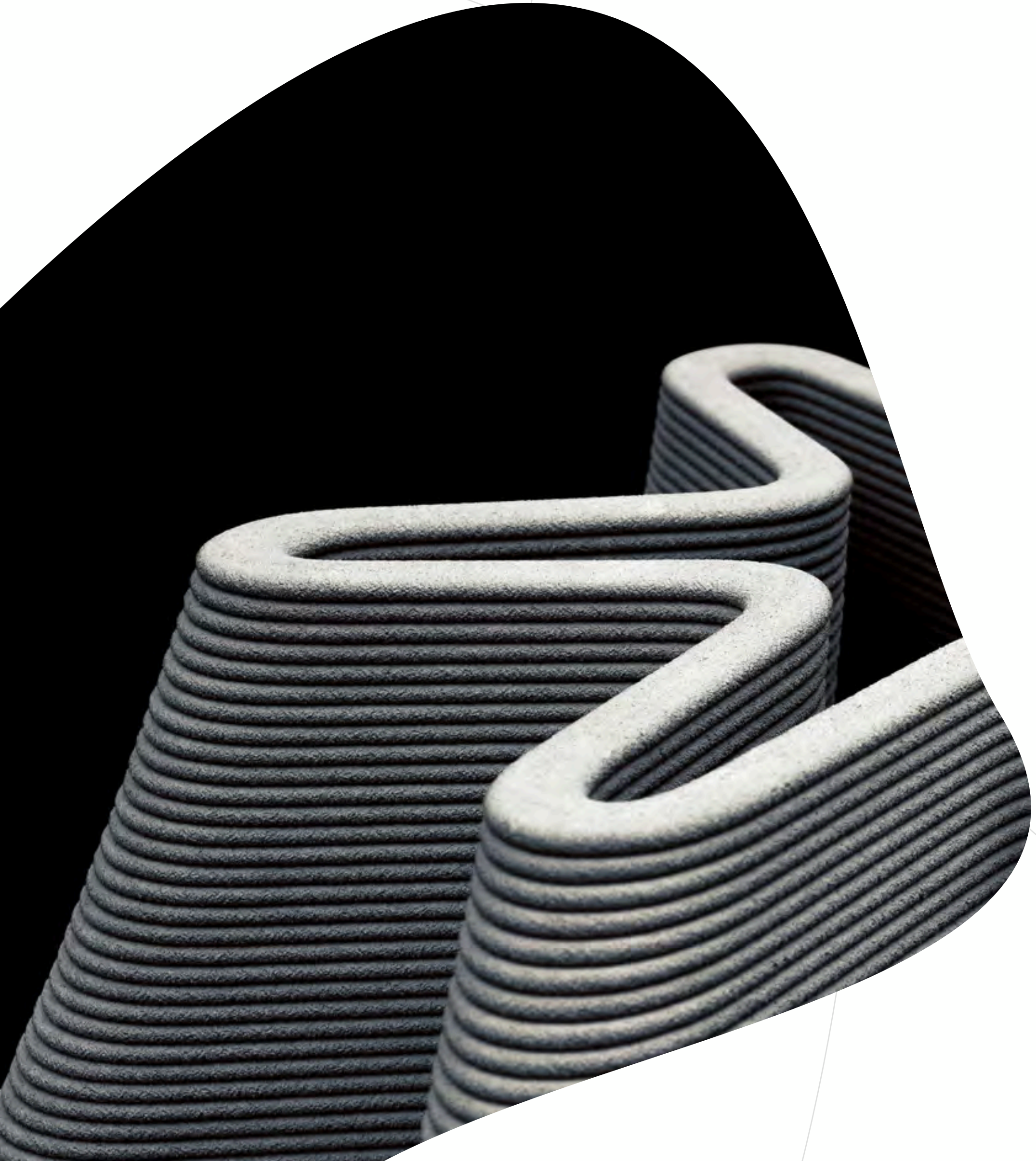


Week 6
Digital Fabrication

This week we will be looking at principles, forms and broad techniques in digital fabrication.

Photo by Ricardo Gomez Angel on Unsplash

Outline

01

Introduction of digital fabrication

Reviewing what we have gathered from previous lectures and moving forward with principles and forms of practice.

02

Techniques in digital architecture

Exploring common strategies such as: folding, forming, tiling/ tessellating, sectioning and contouring.

03

Material strategies

Exploring how material properties drive digital fabrication processes and techniques.

Photo by Muhd Asyraaf on Unsplash

Aims and objectives

- To relate what students have learnt related to digital fabrication in **previous weeks.**
- To elicit the **common techniques**.
- To describe how **materials** can inform fabrication strategies.
- To give **examples** of mentioned techniques.

Learning outcomes

Students will be able to..

01 Summarise **common techniques** used in digital fabrication.

02 Analyse **the use of technique** with regards to computational design thinking practice.

03 Apply the **fabrication knowledge** in their own practice.

(module)

Overarching skills

Software skills

Rhino, Grasshopper, etc

Theory, history and current debate

Understand historical background of this notion and relevant debates.

Research skills

Designing through extensive research

Important concepts

Digital fabrication and construction
Digital design cognition
Human-computer interaction
Digital craftmanship
etc

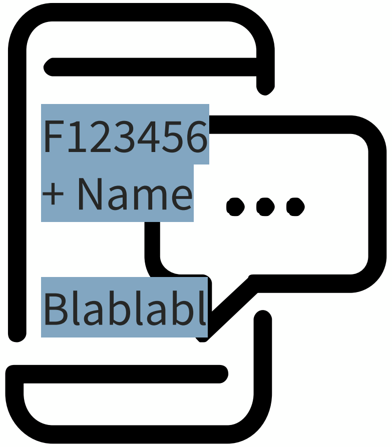
Personal interest

Exploring a preferred scope of design to be developed further

Design precedents

Learning through analysis of completed project

Discussion



Read: supporting material and page 78 of this lecture slides

With the plethora of information in hand at the end of this lecture *(regarding principles, forms, strategies and techniques in digital fabrication)*; **how should architectural pedagogy address this?**
With regards to educating future generation of architects to adapt to changes in technology.

https://miatedjosaputro.com/2020/03/31/week-6-discussion/

Introduction

Previously on week two on historical background

Digital Fabrication

A shift from consumerism to prosumerism
Small-scale digital fabrication machines

Digital fabrication technologies such as CNC-milling machines, laser cutter and 3D printers challenged the mechanism of consumer-based market.*

Claypool, M. (2019). The Digital in Architecture: Then, Now and in the Future. SPACE10

Previously on week two on historical background

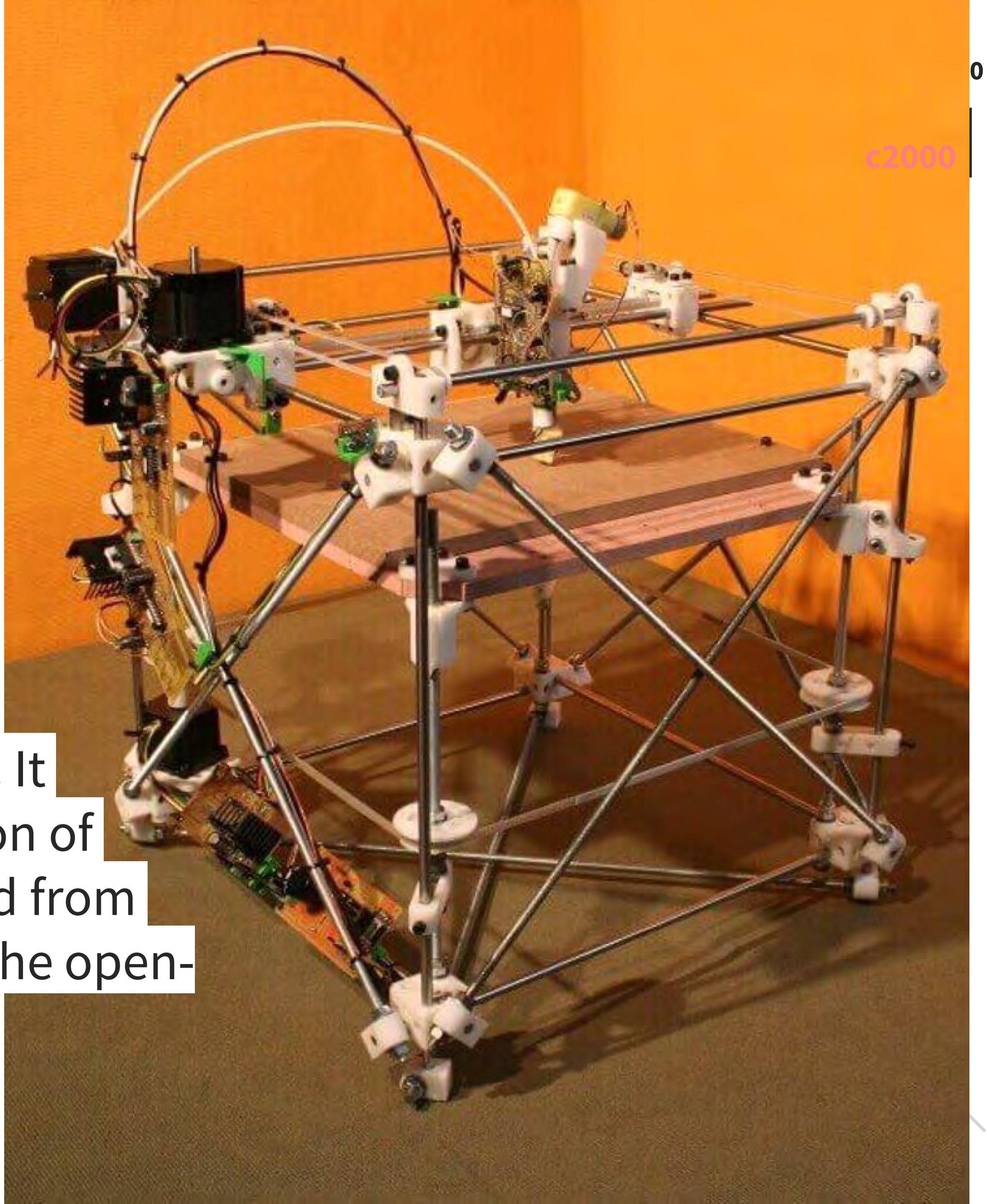
Digital Fabrication

Computer power increases exponentially, became more affordable and therefore more accessible.

Darwin
2004
Adrian Bowyer

First open-source desktop 3D printer. It exemplified the idea of digital fabrication of prosumer. The main idea was originated from *cybernetics* of John von Neumann and the open-source community.

https://all3dp.com/history-of-the-reprap-project/



0

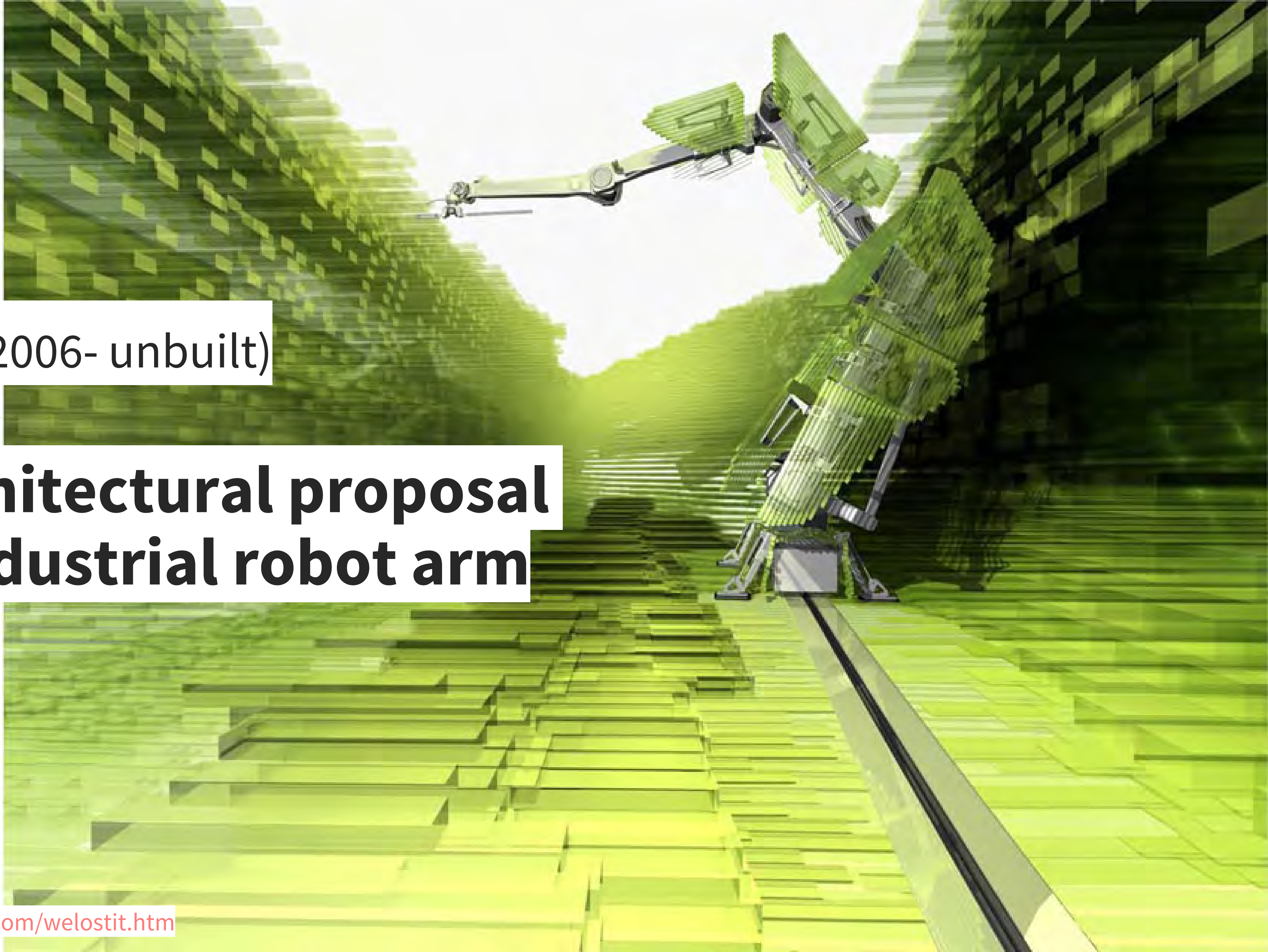
c2000

Olzweg (2006- unbuilt)

First architectural proposal to use industrial robot arm

Olzweg, the robotic arm would have been placed in the courtyard on a moving platform, perpetually construct a space made out of recycled glass by sliding them in and out the place.

https://new-territories.com/welostit.htm

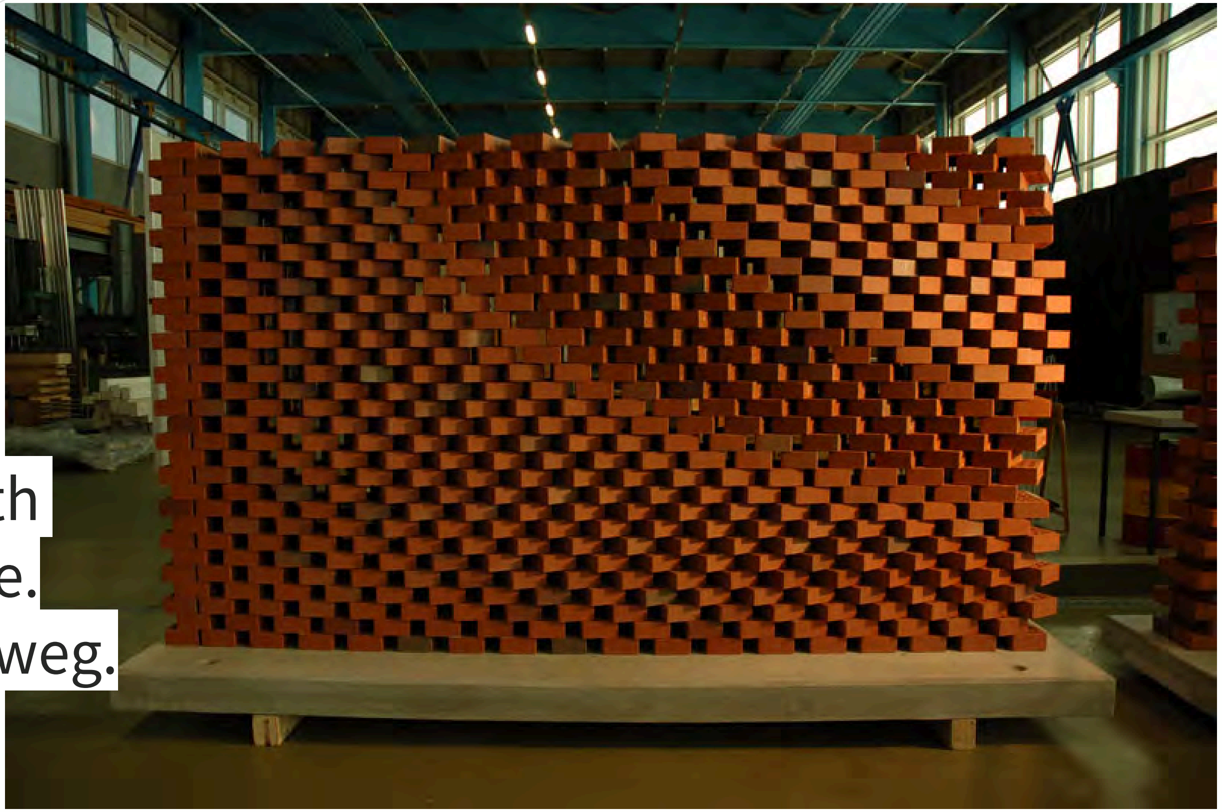


Olzweg (2006- unbuilt)

First architectural proposal to use industrial robot arm

https://new-territories.com/welostit.htm

The Programmed Wall
ETH Zurich
2006



Industrial robot positioned over 400 bricks by using constructive logic, with specific position and rotation in space. The robot is placed similarly with Olzweg.

https://gramaziokohler.arch.ethz.ch/web/e/lehre/81.html

The Programmed Wall
ETH Zurich
2006

https://gramaziokohler.arch.ethz.ch/web/e/lehre/81.html

04.2
FABRICATION

Fabrication, from the Latin for *making by assembly*, is a concept that has undergone an epiphany in the last decade and has rediscovered itself as **“making through computation”**

Fabrication, is generally a **computer-controlled machine fabrication processes**, consists series of technology.

Digital Fabrication is:
A method using digital data to direct a manufacturing process.

Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

Digital information can be generated through:

Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

CAD GEOMETRY
NURBS
MESHES
CURVILINEAR FORMATIONS
PARAMETRIC AND GENERATIVE DESIGN
ALGORITHMIC ARCHITECTURE
MORPHOGENESIS

Principles of digital fabrication

Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

1 **Cutting**

2 **Subtraction**

3 **Addition**

4 **Formation**

Principles of digital fabrication

Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

1
Cutting

Enabling the production of flat components using a cutting head that follows instructions provided by the digital information, to make shape from sheet materials.

Different cutting technologies:

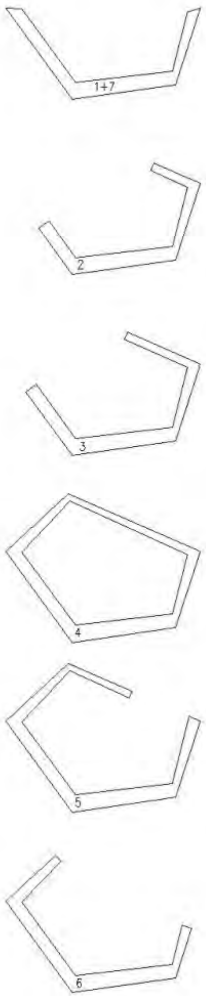
1. Laser-beam*
2. Plasma- arc
3. Water-jet

* Widely known technique

Principles of digital fabrication

1

Cutting



https://miatedjosaputro.com/2014/04/20/digiarchspring2012-one-day-workshop-perspex/

Laser-cut perspex from 6 types of profile

Principles of digital fabrication

2

Subtraction

benjaminuyeda • Following

benjaminuyeda Almost done with the coffee table that we CNCed. We used the 5axis CNC at @buildspc to mill down a reclaimed piece of pine that was 5 feet long and weighed about 200lbs. Thanks to @seamusriley and @ijessup for the help. #cncowners #cnc #architecture #digitalfabrication #modernism #moderndesign #woodcarving #solidwood #reclaimedwood #moderndecor #modernfurniture #homemademodern #cnccarving #architorture

A method using subtractive process, taking material from existing solid volume.

https://youtu.be/YueA6IJ1bgg

Principles of digital fabrication

Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

3

Addition

Using additive technique slowly to build up material in layers. Most commonly known as rapid prototyping.

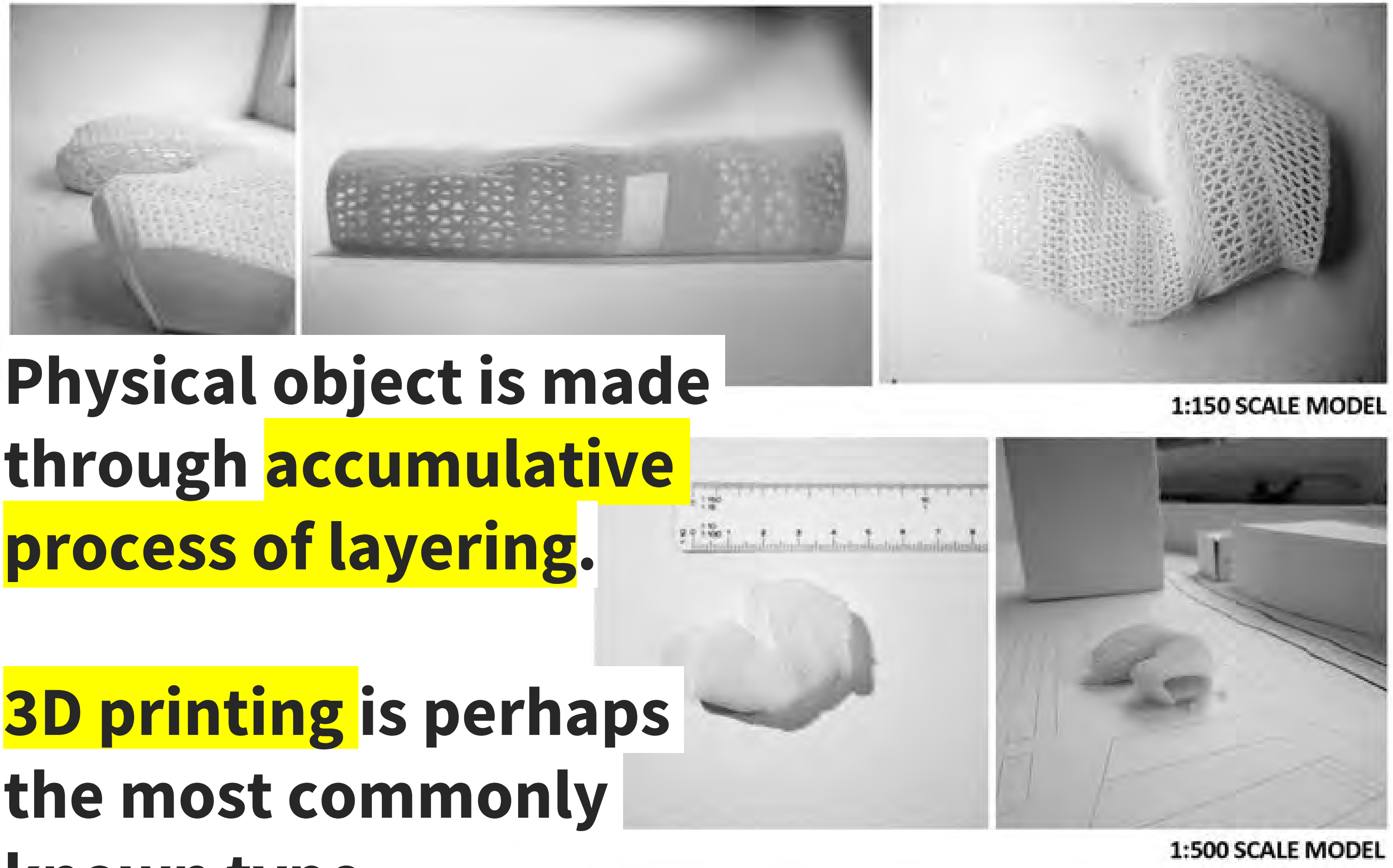
The basis is translating digital information to series of two-dimensional layers.

Principles of digital fabrication

3
Addition

Physical object is made through accumulative process of layering.

3D printing is perhaps the most commonly known type.



https://miatedjosaputro.com/2014/04/12/digiarchautumn2011-a-glimpse-of-final-design/

Principles of digital fabrication

Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

4
Formation

Rather than removing/ building up material, formative fabrication process uses mechanical forces to reshape or deform materials of required shape.

Heat or steam is typically used.

Forms of digital fabrication

Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

01 LASER CUTTING

02 CNC MILLING AND ROUTING

03 RAPID PROTOTYPING

04 3D SCANNING

05 ROBOTICS

Photo by Aswin on Unsplash

Forms of digital fabrication:
1- Laser cutting

Suitable for materials up to 20mm thick.

Provides high degree of accuracy.

Wide range of materials (aluminium, brass, mild and stainless steel and textiles).

Fabrication process is most analogous with conventional methods of physical model making.

Cut from sheet and being assembled to 3D propositions.

Forms of digital fabrication:

1- Laser cutting

55/02

Kielder Art & Architecture and sixteen*(makers) CNC plasma-cut shelter

http://kielderartandarchitecture.com/art-architecture/55-02.html

Forms of digital fabrication:
2- CNC milling and routing

Computer Numerically Controlled (CNC) milling and routing are two most firmly established digital fabrication techniques.

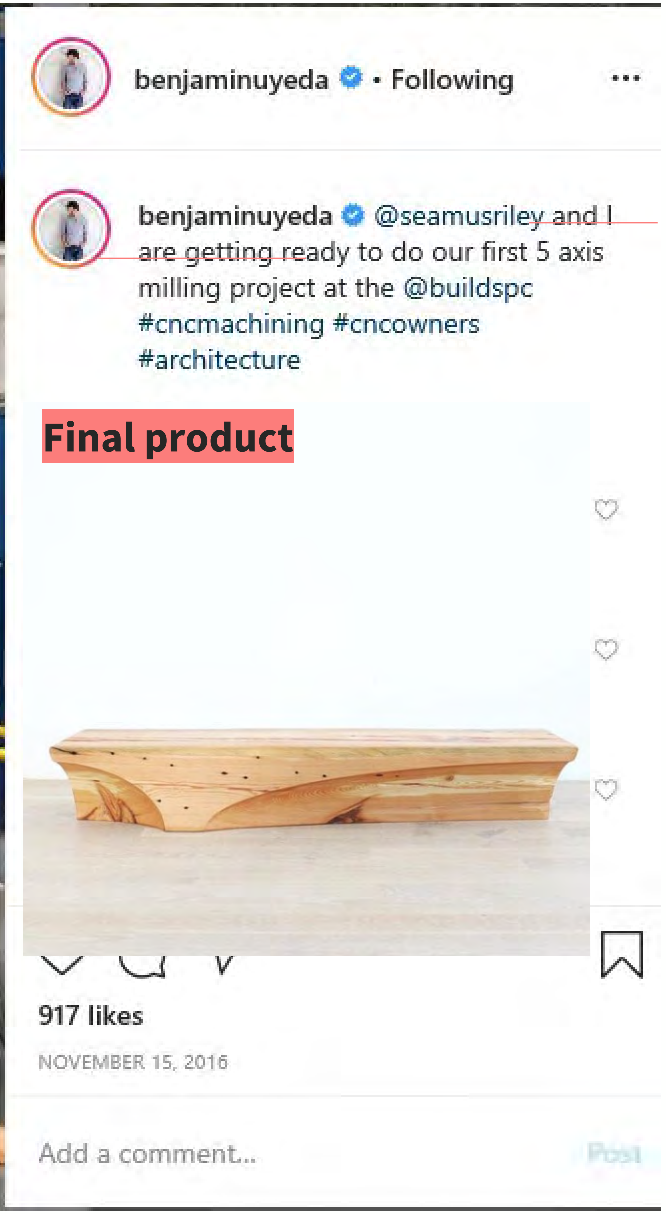
Milling and routing both use rotating cutter to subtract material.

Milling is useful for metals
Routing is typically for wood and plastics.

Forms of digital fabrication: 2- CNC milling and routing

Before

https://youtu.be/YueA6IJ1bgg



Final product

Forms of digital fabrication:
3- Rapid prototyping

Often Rapid Prototyping is mistakenly used as a specific types of additive process, but it is: *a generic term where a family or different methods are related.*

In digital fabrication, layers of starch or ceramic powder are bonded to make objects.

3D printing is the most popular.

Other methods:

Laminated Object Manufacturing (LOM)
Fused Deposition Modelling (FDM)
Multi-Jet Manufacture (MJM)
Selective Laser Sintering (SLS)

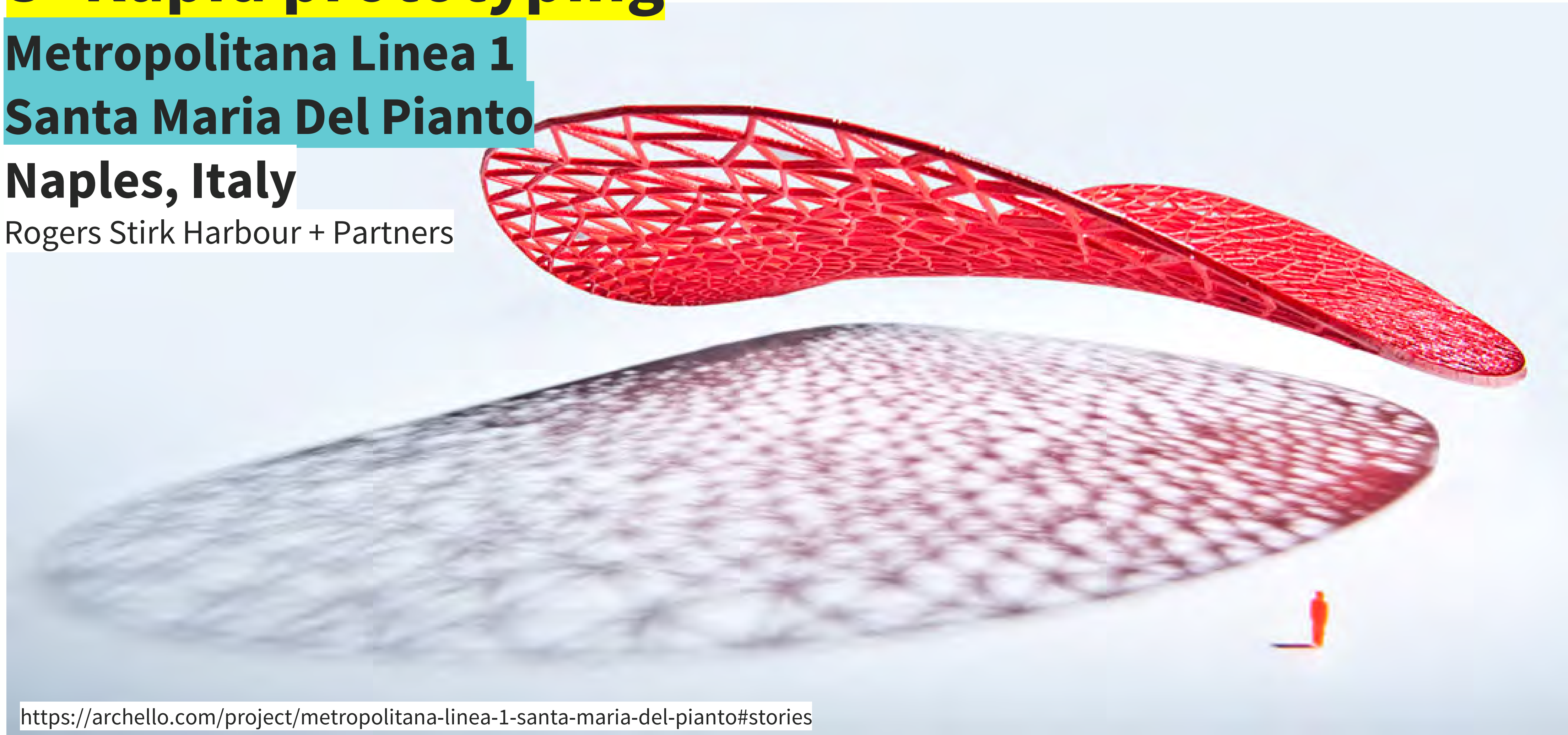
Forms of digital fabrication:

3- Rapid prototyping

Metropolitana Linea 1 Santa Maria Del Pianto

Naples, Italy

Rogers Stirk Harbour + Partners



https://archello.com/project/metropolitana-linea-1-santa-maria-del-pianto#stories

Forms of digital fabrication:
3- Rapid prototyping

Radiolaria

Shiro Studio and D-Shape (2008)

The first 3D mega printer, aimed to demonstrate capabilities of constructing complex geometry. Made from an artificial sand-stone. Three meter high.

http://www.shiro-studio.com/radiolaria.php

Forms of digital fabrication: 4- 3D scanning

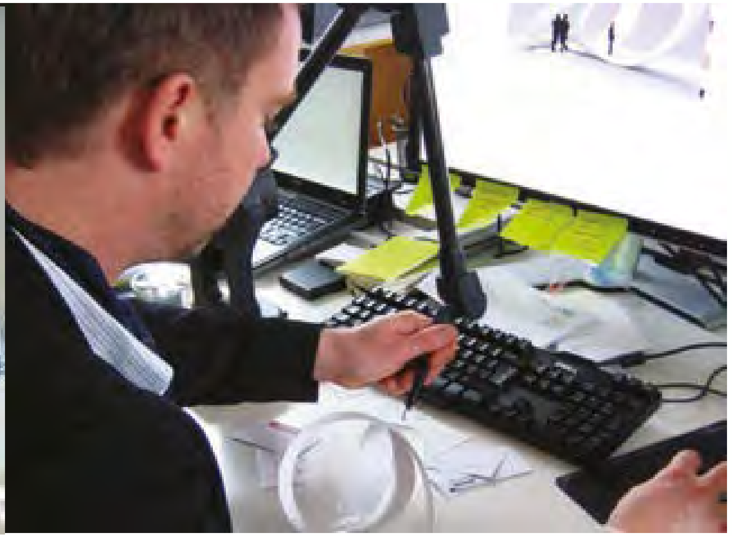
By contrast, 3D scanning inverts relationship between digital information and physical objects.

The technology reads information from physical models and translate it to a digital data, which then can be manipulated further.

Forms of digital fabrication:
4- 3D scanning
Louisiana Pavillion
3XN (2009)

Digitising physical model





https://gxn.3xn.com/project/louisiana-pavilion
Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

Forms of digital fabrication:

4- 3D scanning

Louisiana Pavillion

3XN (2009)

https://gxn.3xn.com/project/louisiana-pavilion

Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

Forms of digital fabrication: 5- Robotics

In contrast with other digital fabrication forms, robotic forms are capable of dealing with complex procedures. And also offer considerable flexibility.

Flexibility in terms of the ability to work in non-cubic space, self-referencing its position in relation to an object.

Compare to a fixed position of machine bed of other forms.

Forms of digital fabrication:
5- Robotics

Mobile Robotic Fabrication System for Filament Structures

Maria Yablonina (2015)

https://www.mariayablonina.com/mobile-robotic-fabrication-system

https://youtu.be/z5C7glwqbeo

Forms of digital fabrication:
5- Robotics

Multi-Material Robotic Fabrication

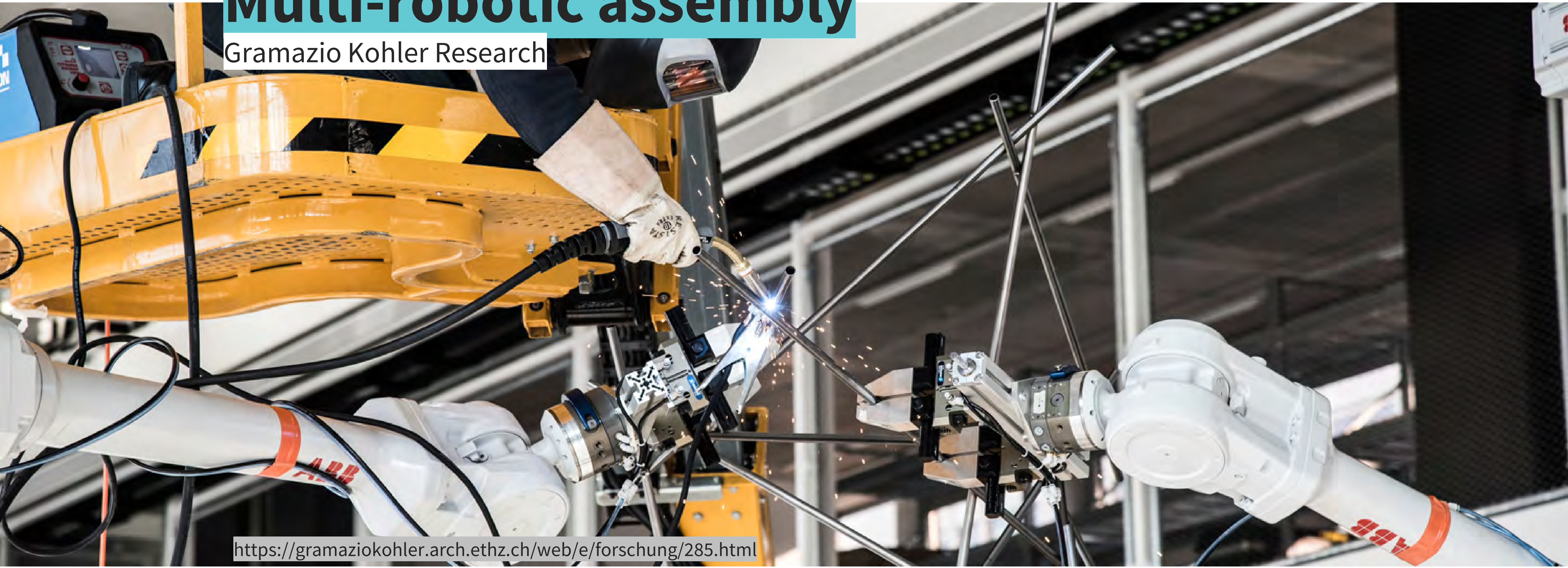
Philip F. Yuan and team,
Digital Futures 2019, Shanghai

Six axis robot, stainless steel, carbon fibre, glass fibre, wood, fabric.

Forms of digital fabrication:
5- Robotics

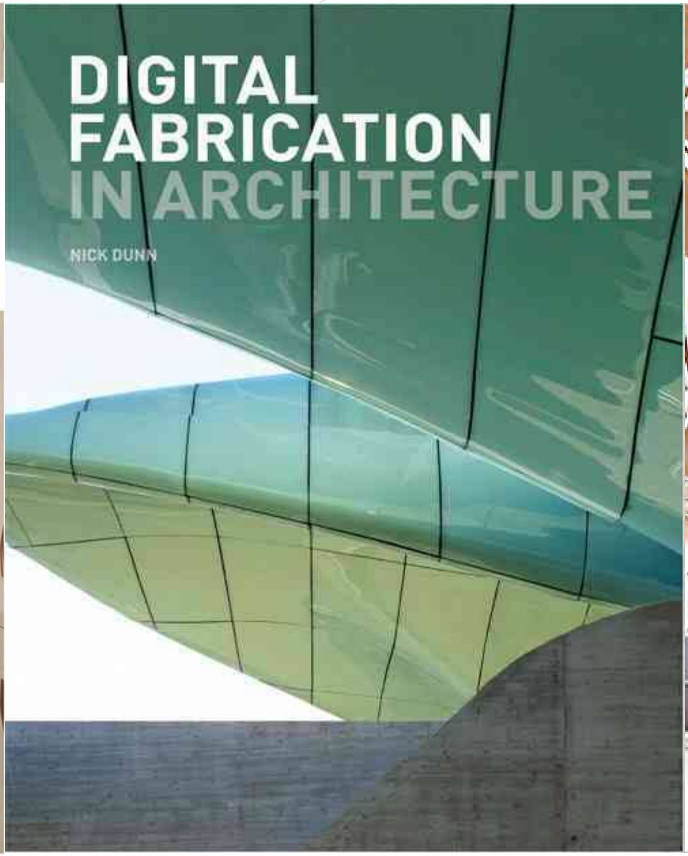
Multi-robotic assembly

Gramazio Kohler Research



https://gramaziokohler.arch.ethz.ch/web/e/forschung/285.html

References to digital fabrication



(1) Iwamoto, L. (2013). *Digital fabrications: architectural and material techniques*, Princeton Architectural Press.
(2) Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.
(3) Yuan, P. F., Leach, N. & Menges, A. (2018). *Digital fabrication*, Tongji University Press Co., Ltd.

Common techniques

Six common techniques

Iwamoto, L. (2013). *Digital fabrications: architectural and material techniques*, Princeton Architectural Press.
Dunn, N. (2012). *Digital fabrication in architecture / by Nick Dunn*, Laurence King.

1. Folding
2. Forming
3. Tiling/Tessellating
4. Sectioning
5. Contouring

Six common techniques: 1- Folding

Folding turns a flat surface into 3D forms, also powerful for creating structure with geometry.

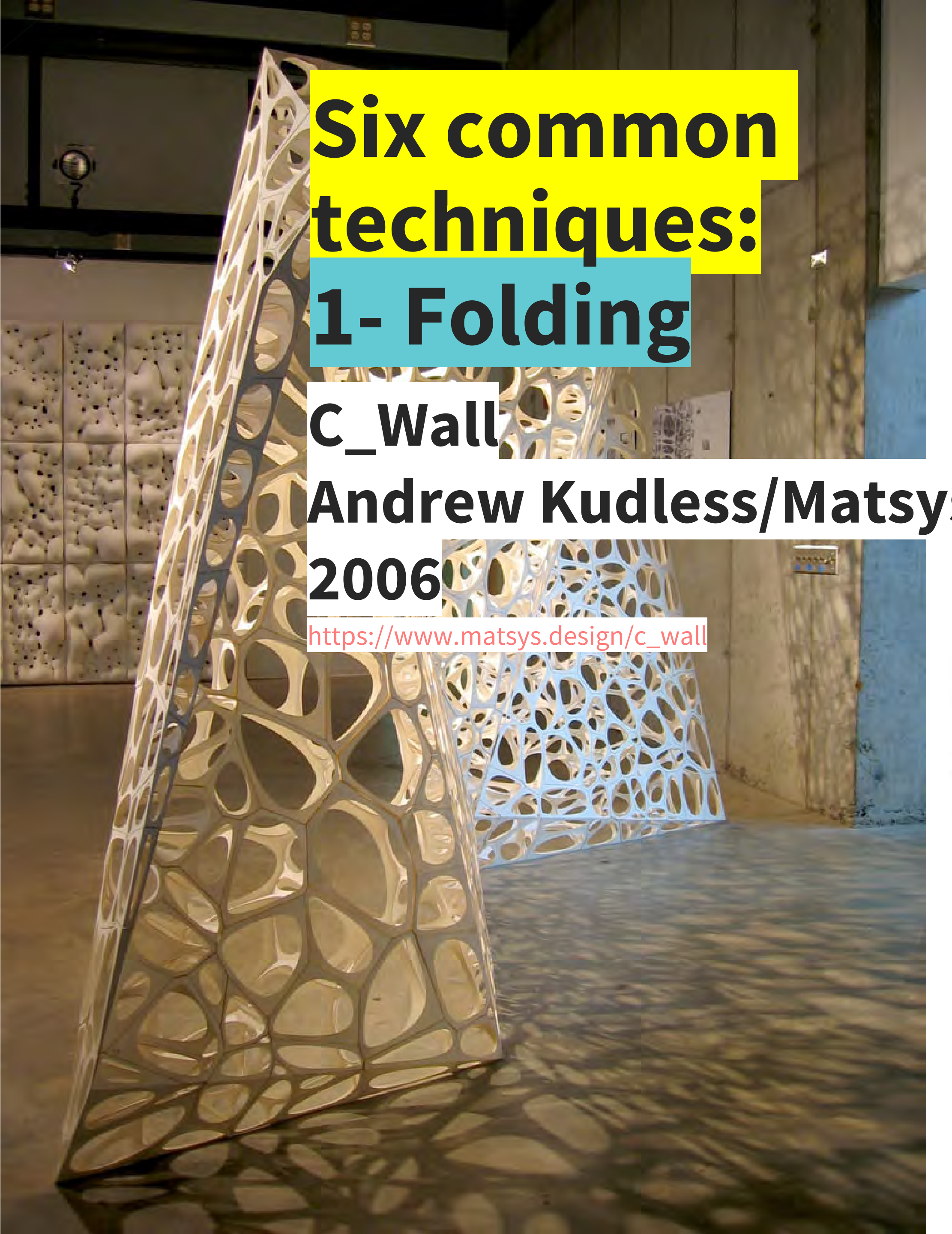
Folding creates fluidity and multifunctionality with continuous surface.

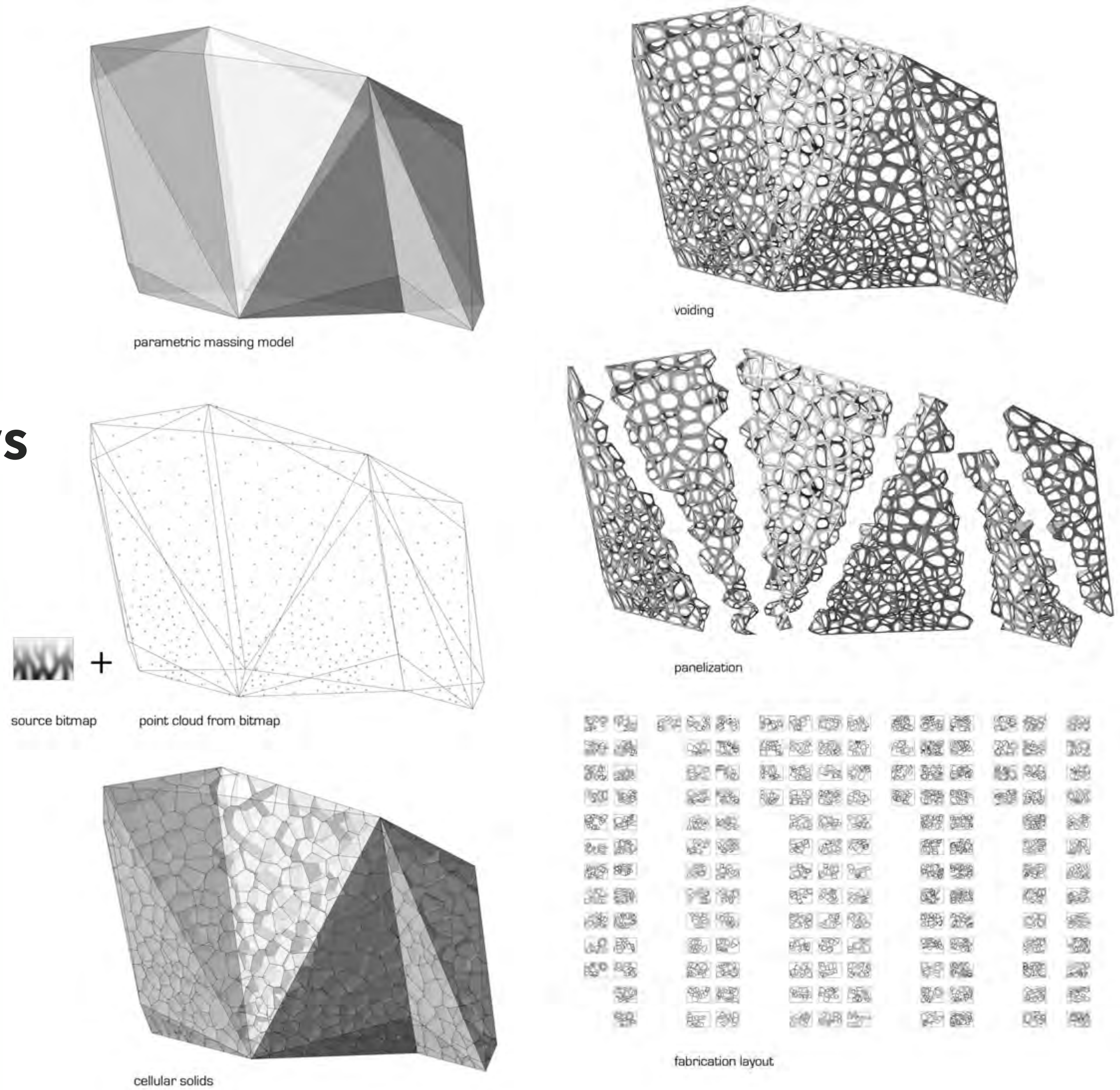
Through folding, self-supporting effective span and rigidity of sheer materials increases substantially.

Six common techniques:
1- Folding

C_Wall
Andrew Kudless/Matsys
2006

https://www.matsys.design/c_wall





Six common techniques:
2- Forming

Forming is tooling through the generation of components from a mould or form.

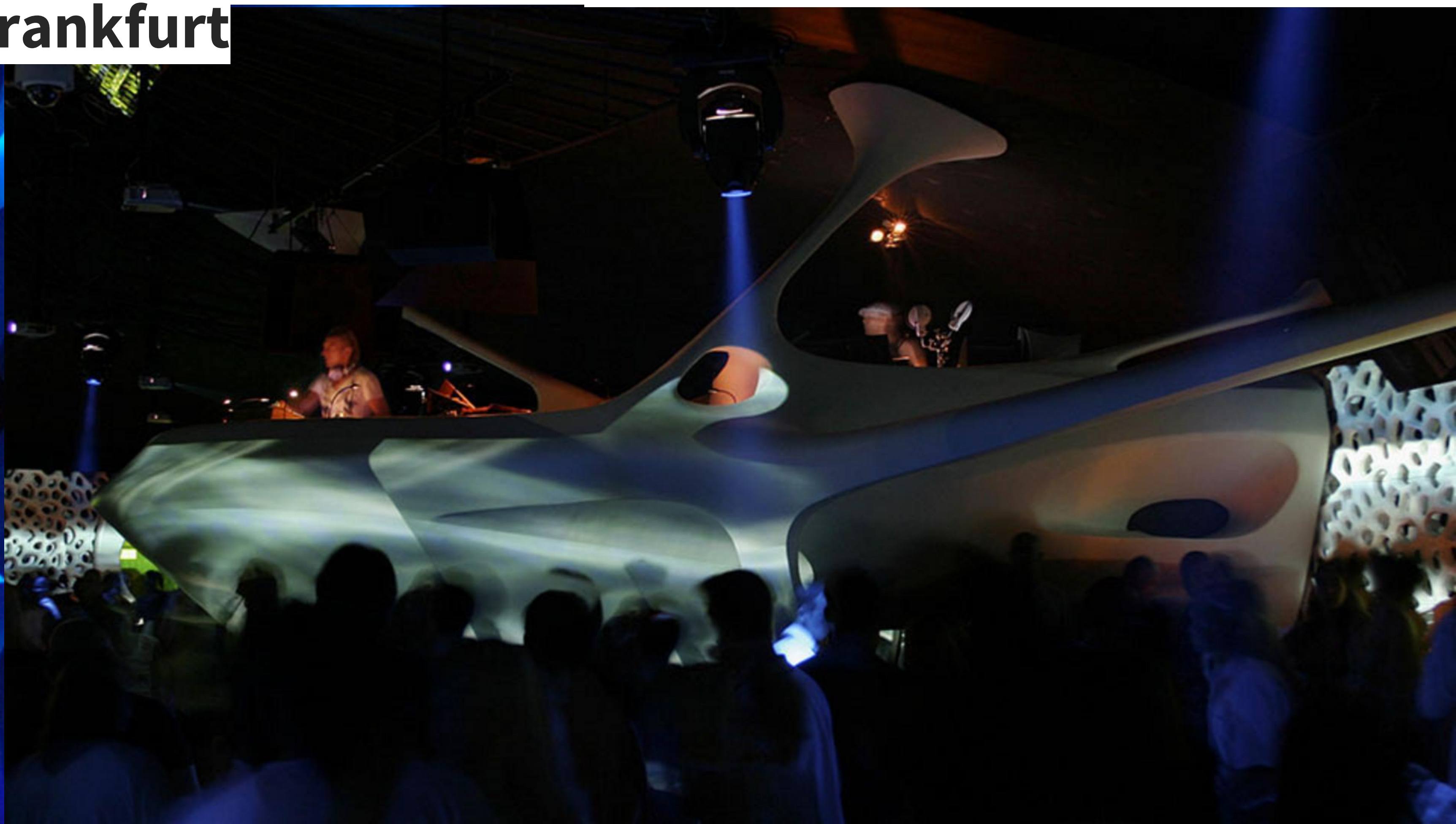
In digital fabrication , it requires mould of form which is usually created by CNC milling machine or rapid prototyping techniques.

Forming generates positive and negative moulds.

Positive: thermo- and vacuum moulding
Negative: facilitate casting and injection moulding.

Six common techniques:
2- Forming

CocoonClub, Frankfurt
3deluxe
2004



Six common techniques:
2- Forming

Alice
Florencia Pita mod
2007

https://www.florenciapita.com/alice

Six common techniques:
2- Forming

Alice
Florencia Pita mod
2007

https://www.florenciapita.com/alice

Six common techniques:
3- Tiling/ Tessellating

It involves development of objects that when assembled together, forming a coherent plane without gaps or overlaps.

Advantages tiling/tessellating in digital fabrication approach:

- Effective time investment
- Provide ways which patterns are generated and optimised (visually and materially sound)
- Optimised for reduction of waste.

Six common techniques:
3- Tiling/ Tessellating

Translating digital information from mesh to complex 3D form, using sheet materials through tiling, has made digital fabrication technique became more apparent from early design stage.

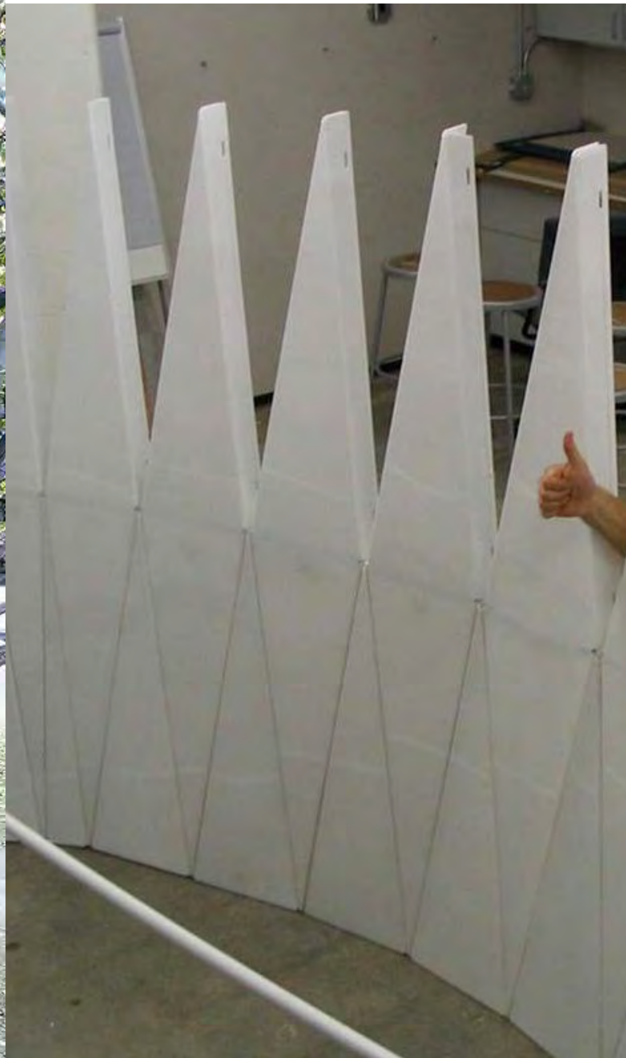
Tiling/tessellating also affords greater variation and modulation, as they provide an inherent economy of means.

Six common techniques:

3- Tiling/ Tessellating

Huyghe + Le Corbusier Puppet Theater, MOS 2004

https://www.mos.nyc/project/puppet-theater



Six common techniques: 4- Sectioning

Sectioning in digital fabrication is a method of profiling components in relation to surface geometry.

Taking sectional cuts through a digital model.

Taking from a long tradition in shipbuilding and aeroplane construction.

Form of object is usually consists of: series of sections and then clad with a skin or a material.

Six common techniques:
4- Sectioning

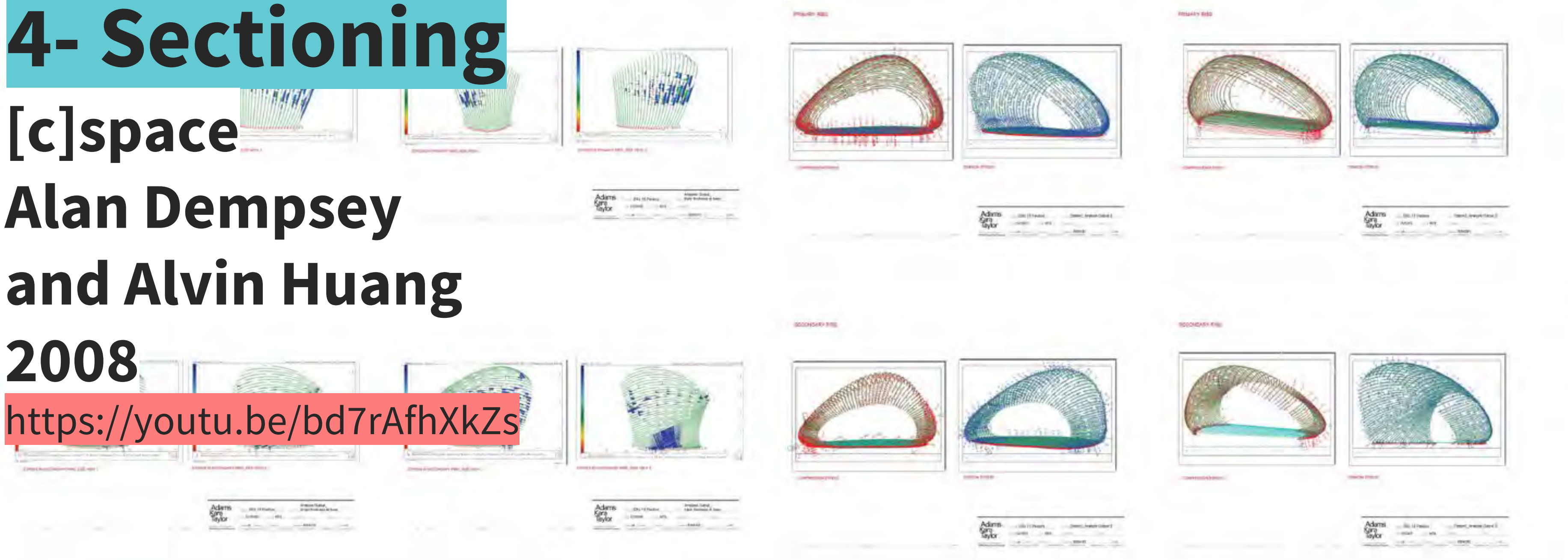
[c]space
Alan Dempsey and Alvin Huang
2008

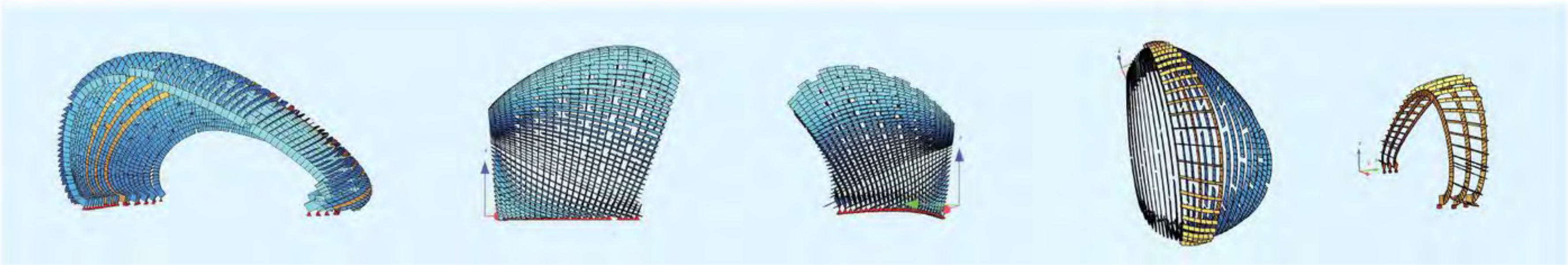
http://cspacepavilion.blogspot.com/

Six common techniques:
4- Sectioning

[c]space
Alan Dempsey and Alvin Huang
2008

https://youtu.be/bd7rAfhXkZs





http://cspacepavilion.blogspot.com/

Six common techniques: 5- Contouring

Contouring is a technique that reshapes sheet materials and create three-dimensional effect by removing successive layers of materials.

A subtractive process, commonly using CNC milling and routing.

Contouring in digital fabrication allows designer to systematically remove material through a series of carvings or contours.

Six common techniques:
5- Contouring

mTable
Gramazio & Kohler
2002

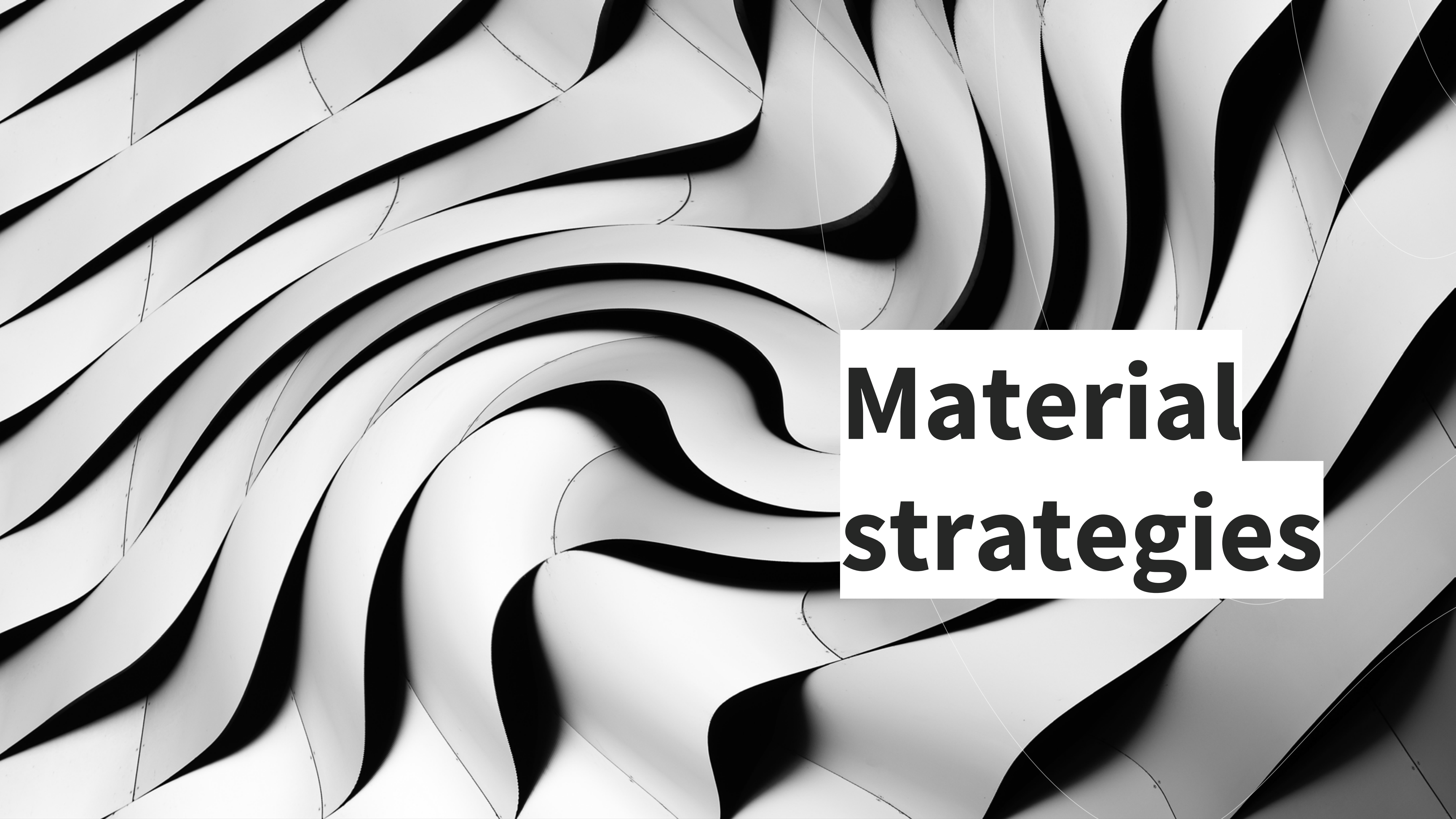
https://youtu.be/CAUL6NosMNc
https://gramaziokohler.arch.ethz.ch/web/e/forschung/17.html

Six common techniques:
5- Contouring

One Main
dECoi
2002

http://www.decoi-architects.org/2011/10/onemain/

Material strategies



Material related techniques

Beorkrem, C. (2017). *Material strategies in digital fabrication*, Routledge.

1. Timber
2. Metals
3. Concrete
4. Hybrids
5. Recycled/ Pre-cycled

Material related techniques: 1- Timber/wood

In digital fabrication, it is an excellent material for testing parametric conditions.

Off-the-shelf wood comes in manageable dimensions (easy and accurately cut), affording many different geometric compositions.

Has a unique phenomenological character, intended to be use in more tactile and intimate ways.

Variety of colour and texture.

Material related techniques:
1- Timber/wood

Digital Arts Center University of North Carolina at Charlotte

https://darts.uncc.edu/image-gallery/ripple-wall

The entire assembly is held together in compression, can only be achieved by the accuracy of CNC tooling.

Plywood offers relatively constant material thickness.

Material related techniques: 1- Timber

Menges, A., Schwinn, T. & Krieg, O. D. (2016). *Advancing wood architecture: a computational approach*, Routledge.

Current limitations:

1. Subtractive fabrication processes (milling and sawing)
2. Multiplicity of applicable norms and regional codes in Germany
3. Data exchange

Material related techniques: 2- Metals

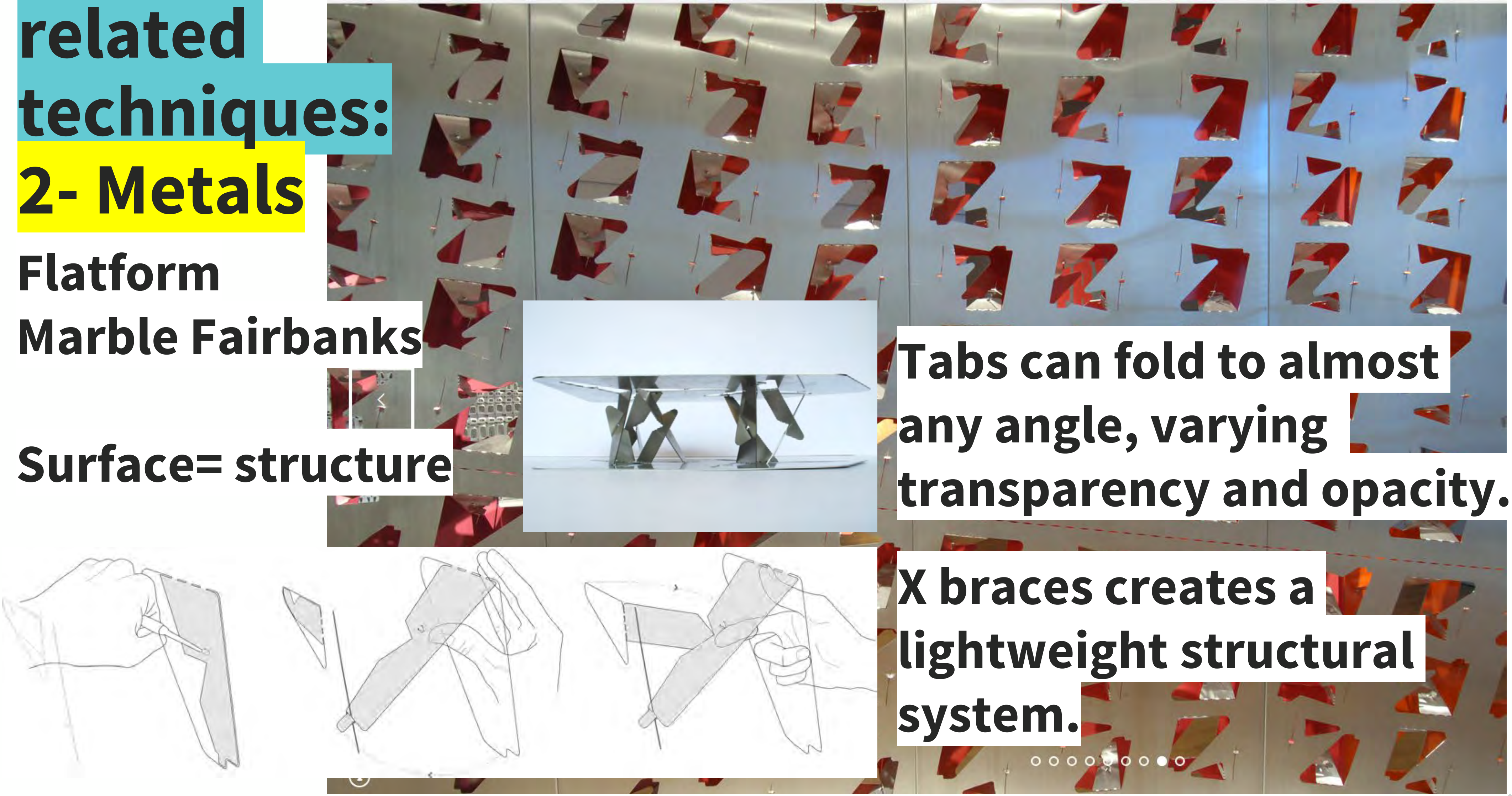
Commonly used in digital fabrication due to its strength and durability, flexibility and simplicity of machining sheet steel.

Most often processed with CNC plasma cutter, laser-cutter and water-jet.

Material related techniques:
2- Metals

Flatform
Marble Fairbanks

Surface= structure



Tabs can fold to almost any angle, varying transparency and opacity.

X braces creates a lightweight structural system.

https://www.marblefairbanks.com/journals/flatform/
https://vimeo.com/74401027

Material related techniques: 3- Concrete /masonry

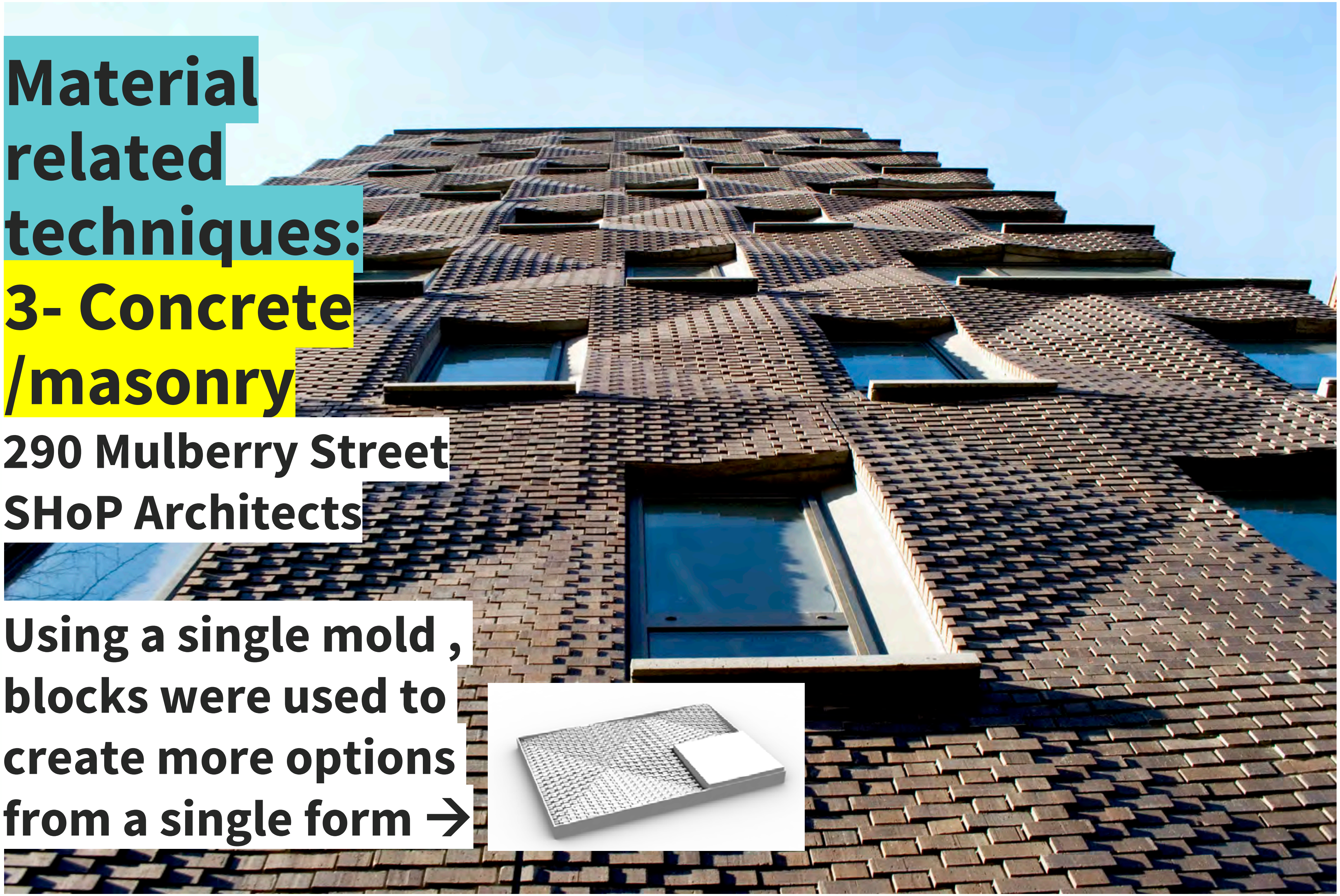
Concrete and masonry are tied together due to their relatively high mass. Usually they do not require tectonic structure.

Works well in compression, but not tension.

Logic of assembly is essential to constraining form.

Material related techniques:
3- Concrete /masonry

290 Mulberry Street
SHoP Architects



Using a single mold , blocks were used to create more options from a single form →

https://www.shoparc.com/projects/mulberry-house/

Material relatec techni

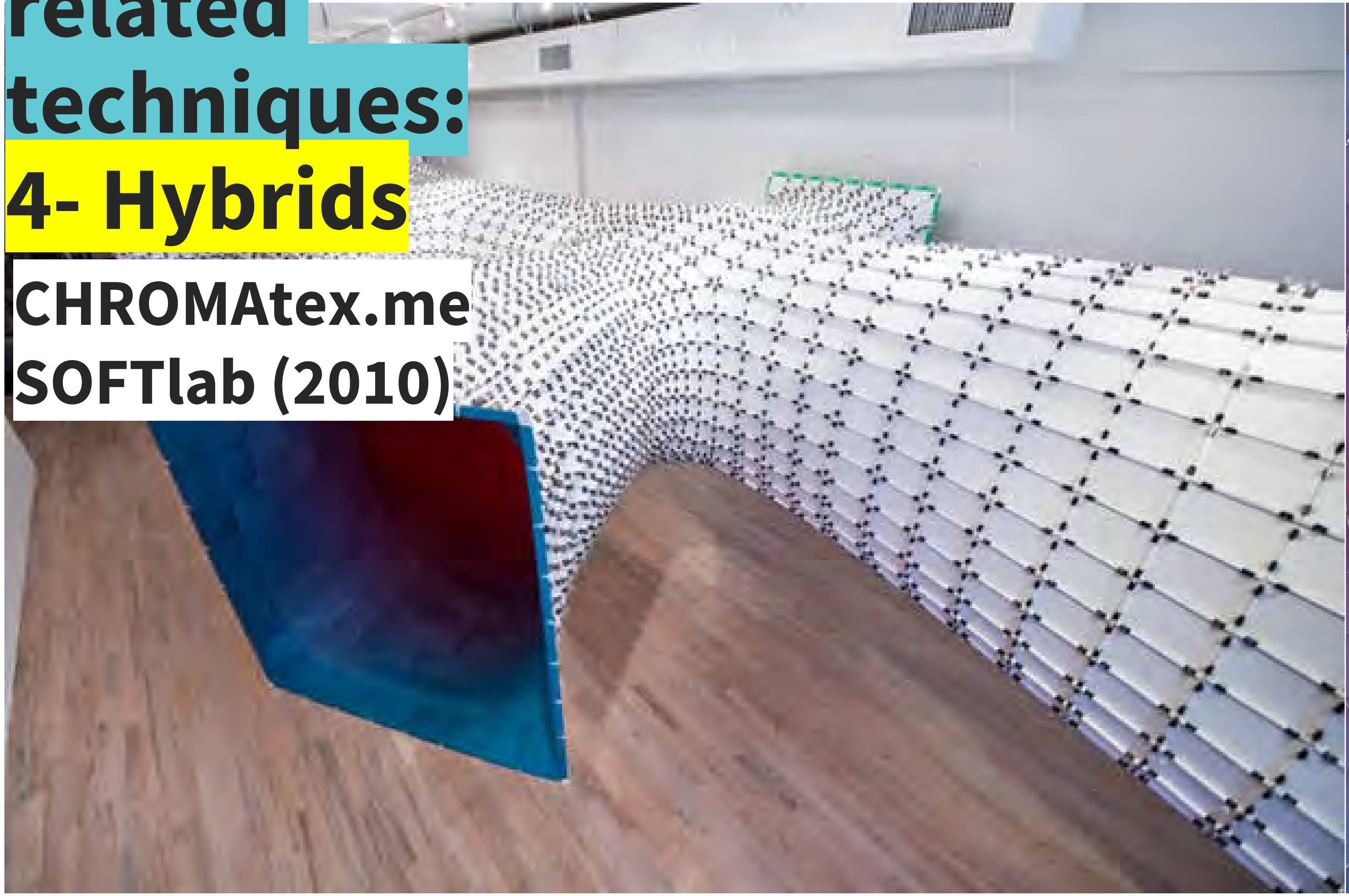
3- Con /maso

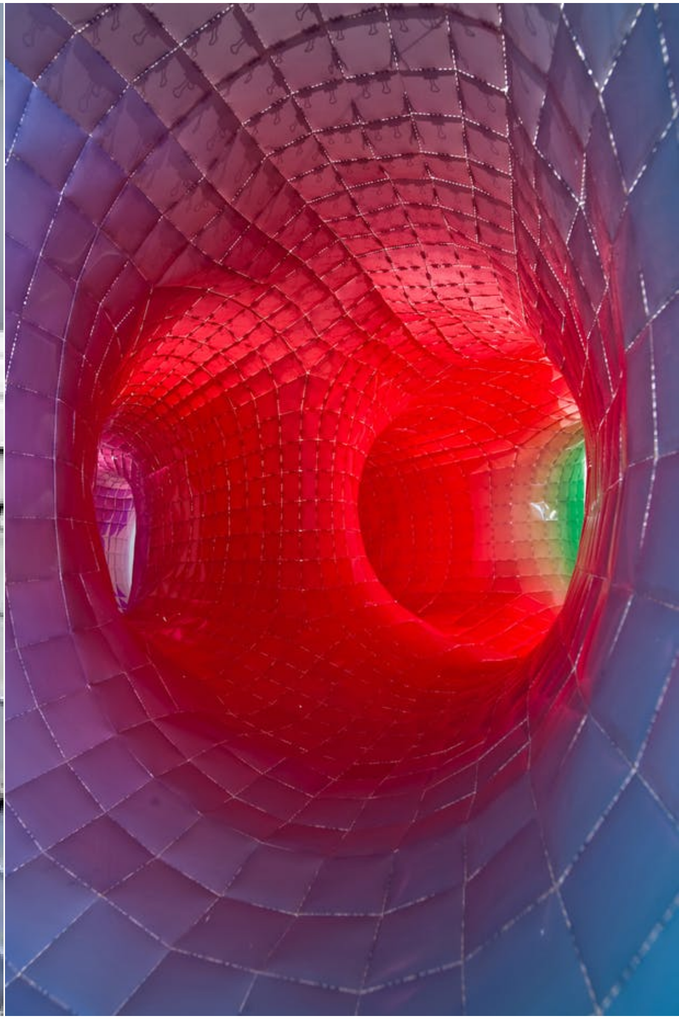
CAADRIA

Embedded video

Material related techniques: 4- Hybrids

CHROMAtex.me SOFTlab (2010)

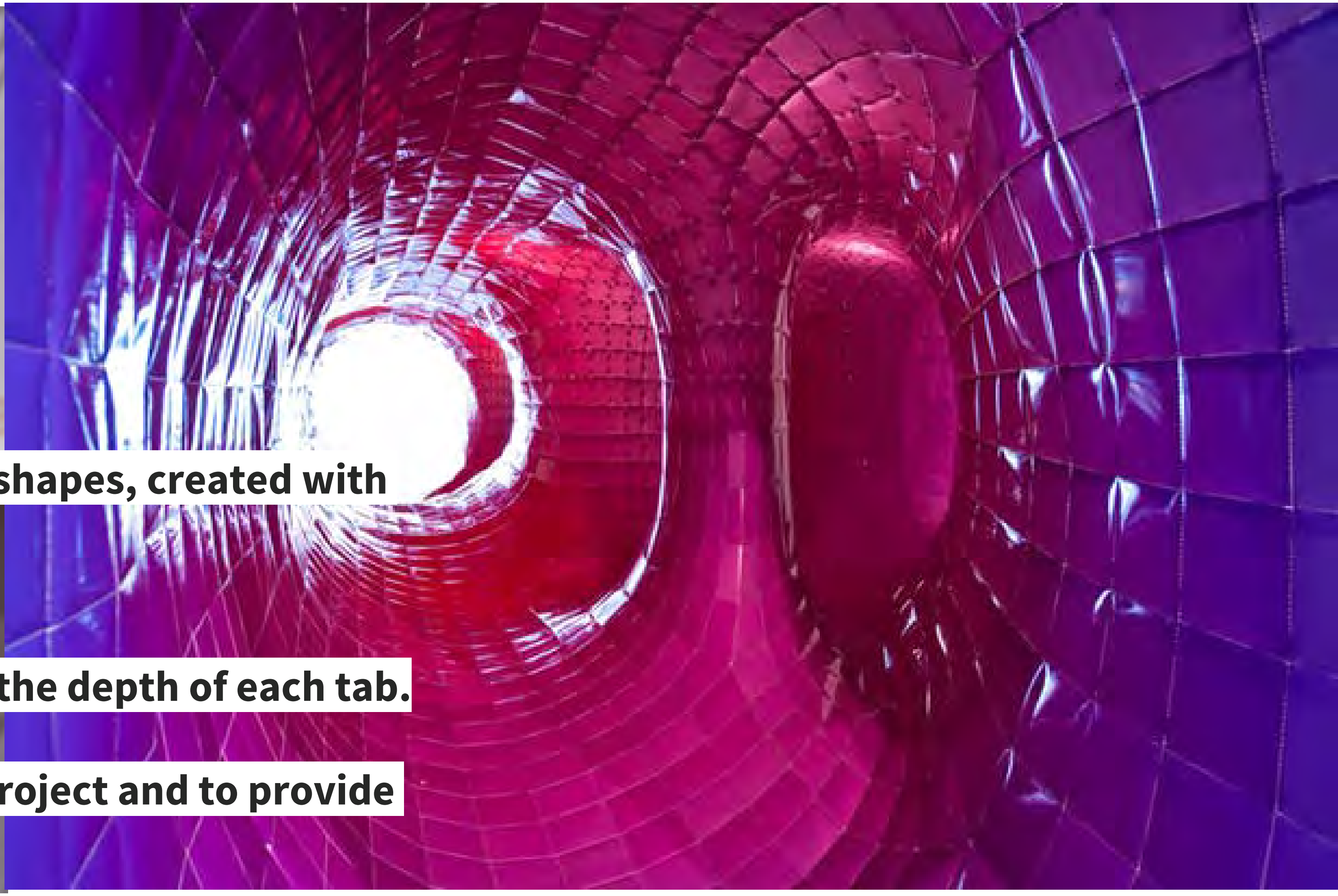




https://www.kickstarter.com/projects/SOFTlab/chromatexme-a-site-specific-installation
https://vimeo.com/14644770

Material related techniques:
4- Hybrids

CHROMAtex.me
SOFTlab (2010)



Tessellated 4000 quadrangle tile shapes, created with laser-cut inkjet printers.

Material constraints:
Size of paper, binder clips define the depth of each tab.

Kickstarter was used to pay the project and to provide flat-pack components.

https://www.kickstarter.com/projects/SOFTlab/chromatexme-a-site-specific-installation
https://vimeo.com/14644770

Material related techniques: 5- Recycled/ pre-cycled

Awareness of temporality of architecture, define necessity that designers become more aware of consumption required for the construction.

Second life after objects are dissembled.

Material related techniques:

5- Recycled/ pre-cycled

Cardborigami

https://www.cardborigami.org/

A pop-up shelter made from card board as: shelter for the unhoused, disaster preparedness and social enterprise.

https://youtu.be/iA3U293DlE4

Material related techniques:
5- Recycled/ pre-cycled

Cardborigami

Nearly 100% cut sheet.
Primarily geometry is based on the ability to be compressed into a flat unit

Cardborigami at Brea Gallery (2016)

https://www.cardborigami.org/

Others

Contextualising the affordable technology within the current COVID-19 pandemic:

https://www.dezeen.com/tag/coronavirus/

Coronavirus

UN and WHO launch Global Call Out To Creatives to make informative coronavirus visuals

The United Nations has launched an open competition for creatives to design informative works that accurately communicate public health messages in a bid to "flatten the curve" of the coronavirus pandemic.
More ›

Natashah Hitti | 16 hours ago | 2 comments

Daily coronavirus architecture and design briefing: 30 March

Daily coronavirus briefing: today Dezeen is launching a new daily briefing, rounding up news about the coronavirus pandemic that is relevant to the global architecture and design community. Read our first briefing below and keep up to date with our coronavirus coverage here. More ›

Tom Ravenscroft | 22 hours ago | Leave a comment

Coronavirus reveals "the shortcomings of the traditional supply chain" says Bjarke Ingels

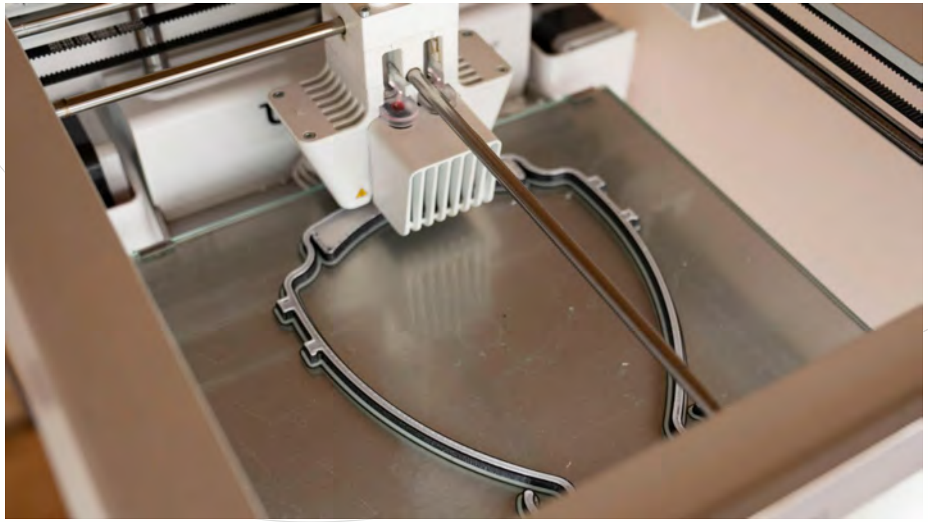
Decentralised local manufacturing could replace global supply chains as a result of the coronavirus pandemic, according to architects who collaborated on an open-source project to make face shields for hospital workers.
More ›

Marcus Fairs | 30 March 2020 | 9 comments

American architects mobilise to make coronavirus face shields for hospital workers

Architects across America including BIG, KPF and Handel Architects have teamed up as part of an open-source project to manufacture face shields to protect hospital workers treating coronavirus patients. More ›

Marcus Fairs | 29 March 2020 | 17 comments



https://www.dezeen.com/2020/03/29/american-architects-coronavirus-face-shields-hospital-workers/

Innovation Leadership Money Business Small Business

Calling All Makers With 3D Printers: Join Critical Mission To Make Face Masks And Shields For 2020 Healthcare Workers

TJ McCue Senior Contributor
Consumer Tech

March 25 Update: I continue to update and modify this post, usually at the end, unless noted elsewhere.

After seeing the N95 shortage gripping the nation's healthcare workers, HP Inc. and partners have mobilized to create 3D printed face mask and face shield solutions, plus a few other innovative ideas, to keep people safe during the COVID-19 outbreak.

HP 3D Printed Masks for COVID-19 response; Designed by research institute CIIRC CVUT HP AND CIIRC CVUT

HP is, of course, one of the largest and best known companies in the world, putting their enormous might alongside other efforts to create alternate personal protection equipment (PPE) is significant (and needed). However, they are not the only ones doing this and I will share a number of initiatives taking place from small to large (including some of the ones I mentioned in the DIY Face Mask post as well as the N95 Mask post).

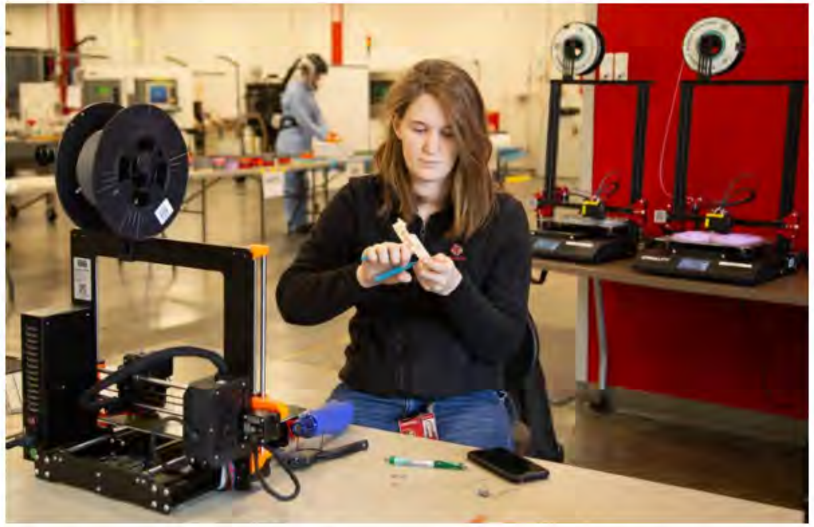
Click here for link

ENGINEERING STUDENTS PRODUCING 3-D PRINTED FACE SHIELDS FOR HEALTHCARE PROFESSIONALS

March 24, 2020

The effect of the pandemic COVID-19 has caused a sea change in the activities of living in communities around the world. Work, school, recreation, retail, medical care; everything has been altered, causing anxiety. Many have expressed a sense of frustration or helplessness because they feel there is nothing they can actively do to help – this virus is unprecedented. But for Speed School engineers at the University of Louisville, creating innovative solutions for the most complex problems – and taking action – is what they do best.

The Additive Manufacturing Institute of Science and Technology (AMIST) facility at Speed School of Engineering has risen to this challenge by contributing something vital to the pandemic: protective face shields for healthcare workers, an item currently in a critical shortage due to tightening of hospital supply chain lines. The original impetus for the project was a request for 100 of the shields from the Internal Medicine Department at University of Louisville Health.



Graduate assistant and student Kate Schneidau oversees the 3D printing of face shield for local health care professionals in response to the shortage caused by the COVID-19 pandemic.

Created with state of the art 3-D printing technology, the team has been printing face shields at their core facility, increasing their production output to 55 shields per day by running continuous shifts from 8 a.m. to midnight daily.

Director of Workforce Development at AMIST, Ed Tackett is coordinating the COVID-19 Speed School Response Team. "We asked ourselves, 'what can we do right now?' How do we protect our most vulnerable citizens and how can the University play a positive role in making that happen?" said Tackett. "We have medical professionals literally on the front lines, and if we can help them be safer or keep them from getting sick, we're going to do whatever we need to do to make that happen," said Tackett.

What Tackett needed was a dedicated and talented production team. He got that team with graduate assistant Kate Schneidau and four other Speed School students who wanted to help however they could with this health crisis. Schneidau is the production manager who helps manage the scheduling of shifts totaling 16 hours a day, and ensures that builds are continuously running, so they can output as many face shields as possible in a day.

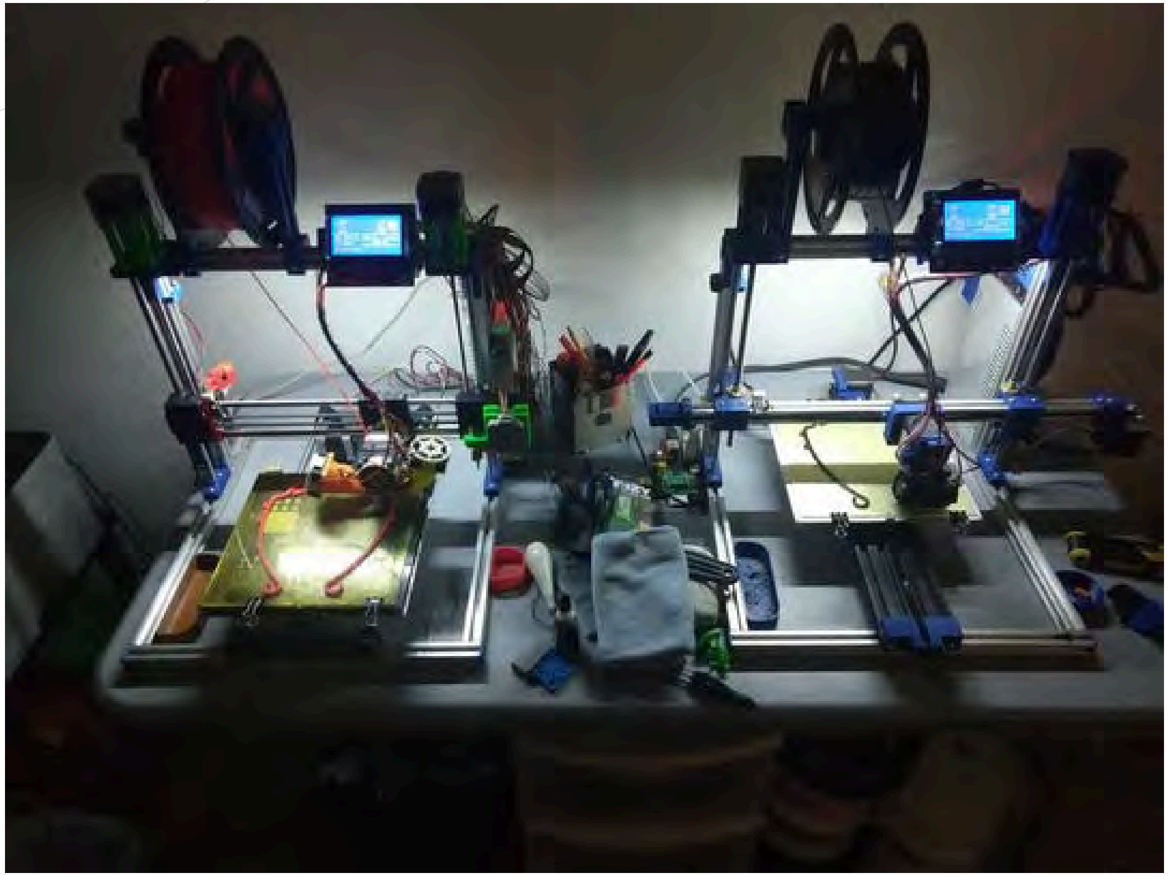
Schneidau said she feels a sense of pride knowing that she is contributing skills she learned at Speed School in such a direct way to benefit the community. "It's more than just helping produce a product that can be sold commercially. It's a sense of camaraderie with the community knowing in tough times I can still help. I was taught all my life if somebody needs help, you step up and help as much as you can without expecting anything, because it's the right thing to do."

The first batch of 100 face shields will be picked up today, and while the face shield production is filling the gap until the medical supply chain catches up, the Additive Manufacturing center is nimble and can adapt quickly to new 3-D printing needs that may arise due to COVID-19.

https://engineering.louisville.edu/students-producing-3-d-printed-face-shields-for-healthcare-professionals/

Locals making 3D-printed face shields for medical centers

Claire Kowalick, Wichita Falls Times Record News Published 3:05 p.m. CT March 30, 2020 | Updated 7:48 p.m. CT March 30, 2020



https://www.timesrecordnews.com/story/news/local/2020/03/30/locals-making-3-d-printed-face-shields-medical-centers/5087354002/

For forum post:

https://miatedjosaputro.com/2020/03/31/week-6-discussion/

As other design tools, there are limits and tolerances of working with digital fabrication techniques.

Through negotiation of constraints, it often sparks creativity.

How can education offer to facilitate young minds to exploit full potentials of technology?

Open (source) digital fabrication:

Schneider, C. (2018). *Opening digital fabrication: transforming TechKnowledgies*, KIT Scientific Publishing.

fablab

Location: 1500 registered 'fab labs' in the world

https://fabfoundation.org/

Lasersaur

Open source laser cutter

Re-iterating aims and objectives

- To relate what students have learnt related to digital fabrication in **previous weeks.**
- To elicit the **common techniques**.
- To describe how **materials** can inform fabrication strategies.
- To give **examples** of mentioned techniques.

Summary

The shift in how designers think-draw-make is prominent with the approach of digital fabrication. In terms of the process of: generation digital data, integrating digital information and fabrication, tooling consideration *(include considering material properties and constraints),* **fabricating to finishing.**