Designing 3D-Printed Deformation Behaviors Using Spring-Based Structures

An Initial Investigation

Liang He, Huaishu Peng, Joshua Land, Mark D. Fuge, Jon E. Froehlich

MAKEABILITY LAB

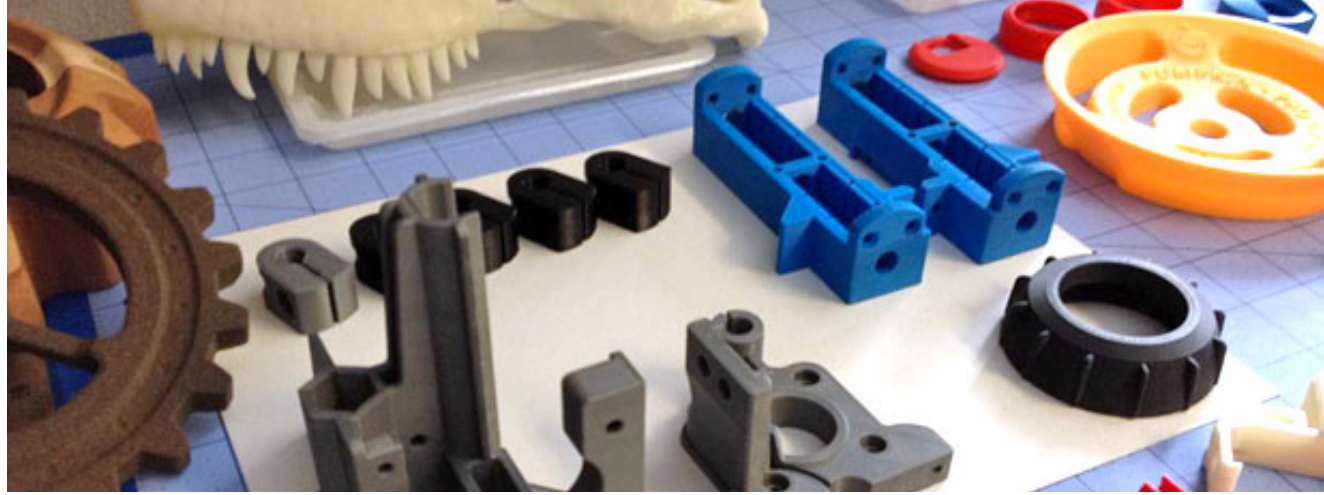
DESIGN USE BUILD

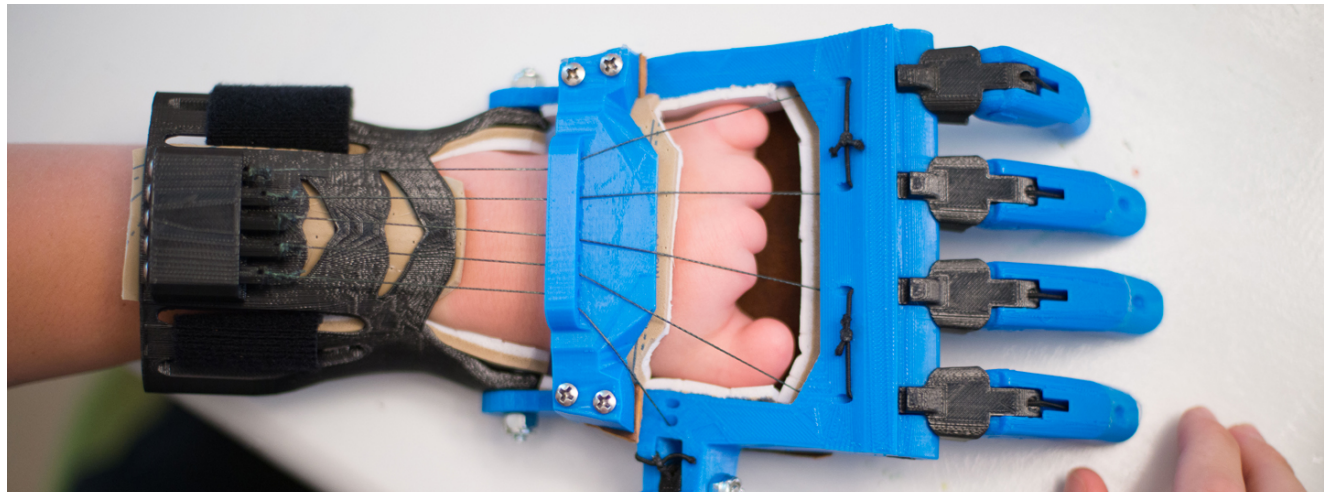
UNIVERSITY OF MARYLAND

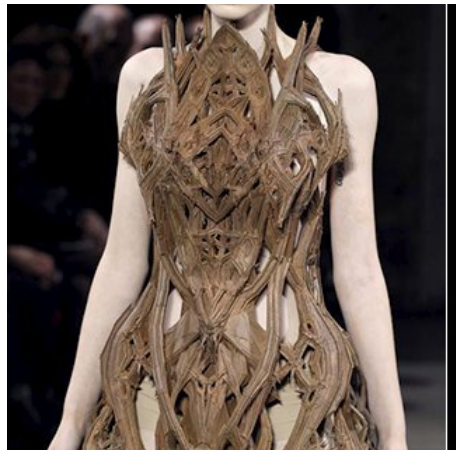
CORNELL UNIVERSITY FOUNDED A.D. 1865

Cornell CIS
COMPUTING AND INFORMATION SCIENCE

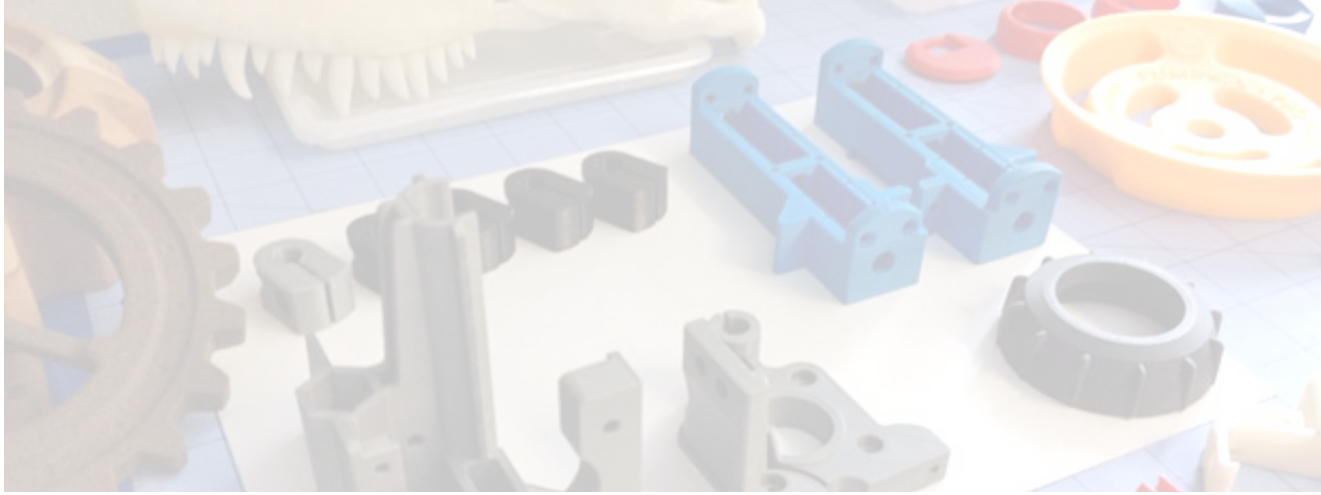
3D printing enables people to rapidly make things, create useful devices, and design new fashion

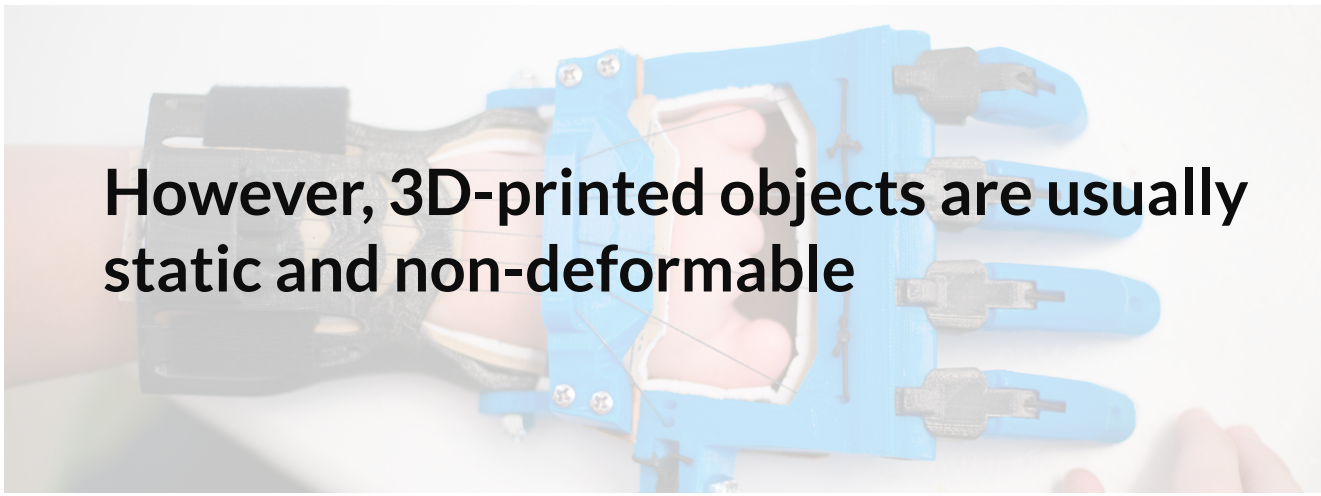






3D printing enables people to rapidly make things, create useful devices, and design new fashion





However, 3D-printed objects are usually static and non-deformable

How can we…

make deformable 3D-printed objects?

How can we…

make deformable 3D-printed objects?

Compound Materials

New Fab Machines

Mechanical Structures

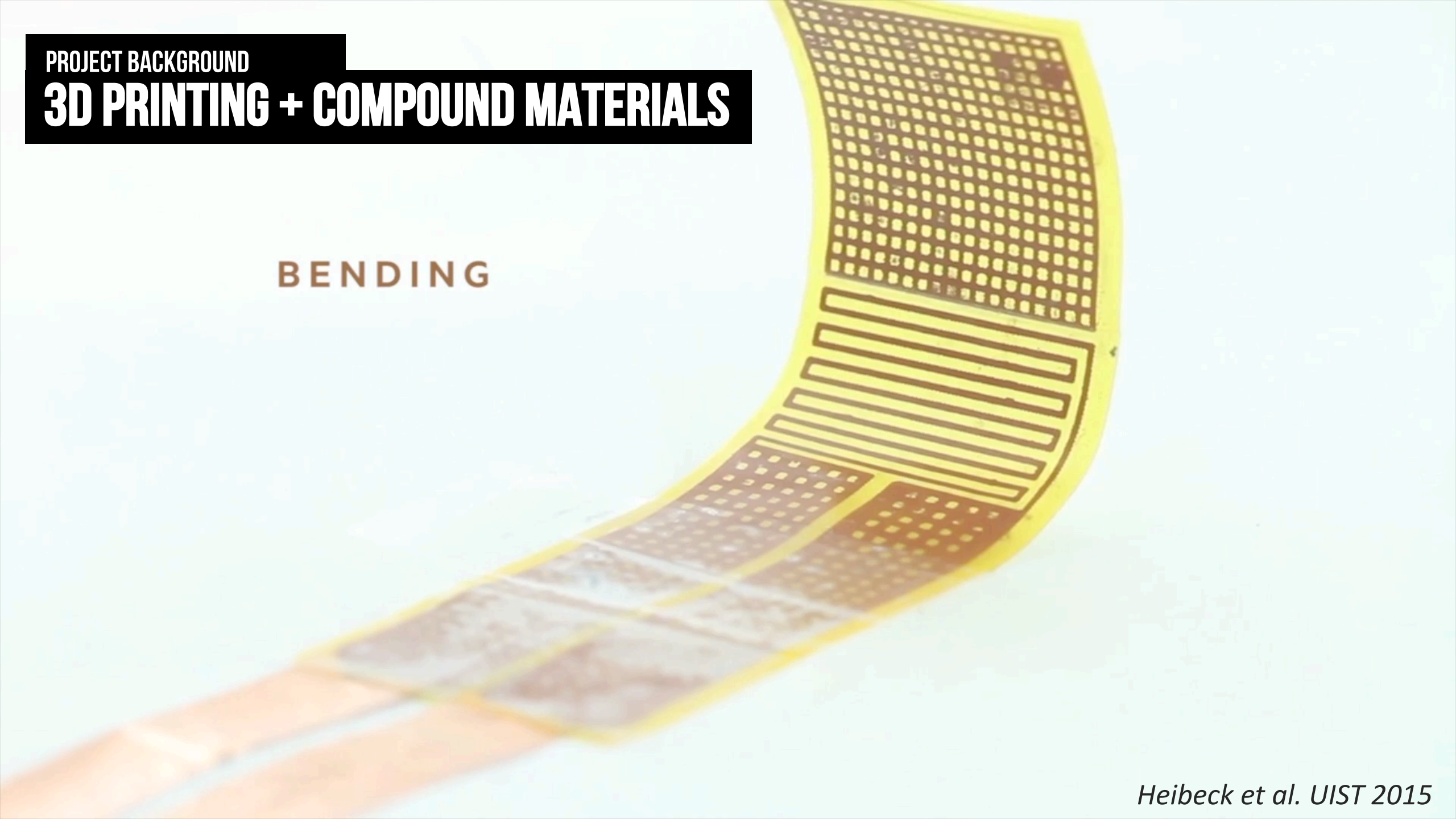
PROJECT BACKGROUND

3D PRINTING + COMPOUND MATERIALS

Ou e t al. UIST 2016

PROJECT BACKGROUND

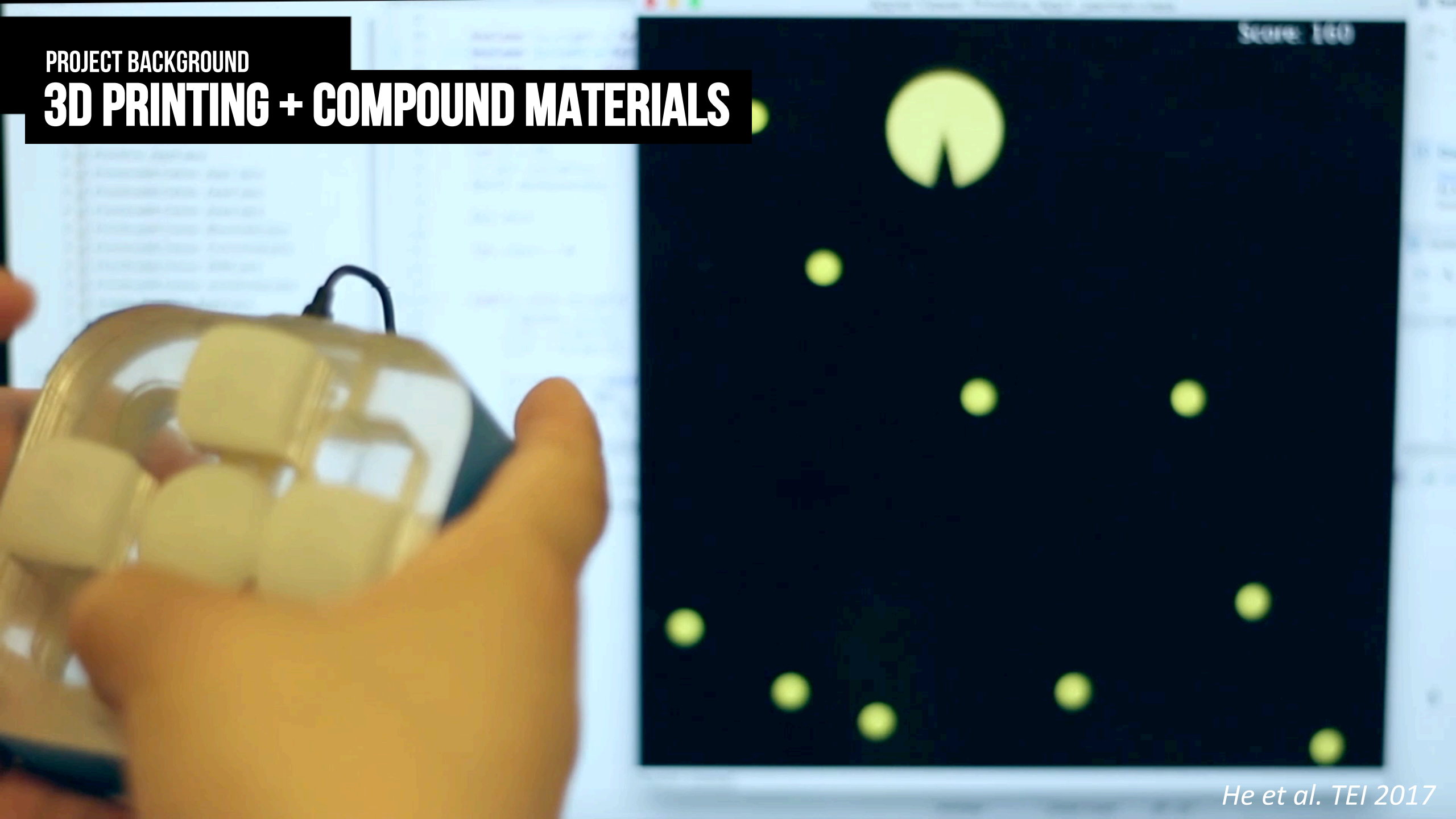
3D PRINTING + COMPOUND MATERIALS



Heibeck et al. UIST 2015

PROJECT BACKGROUND

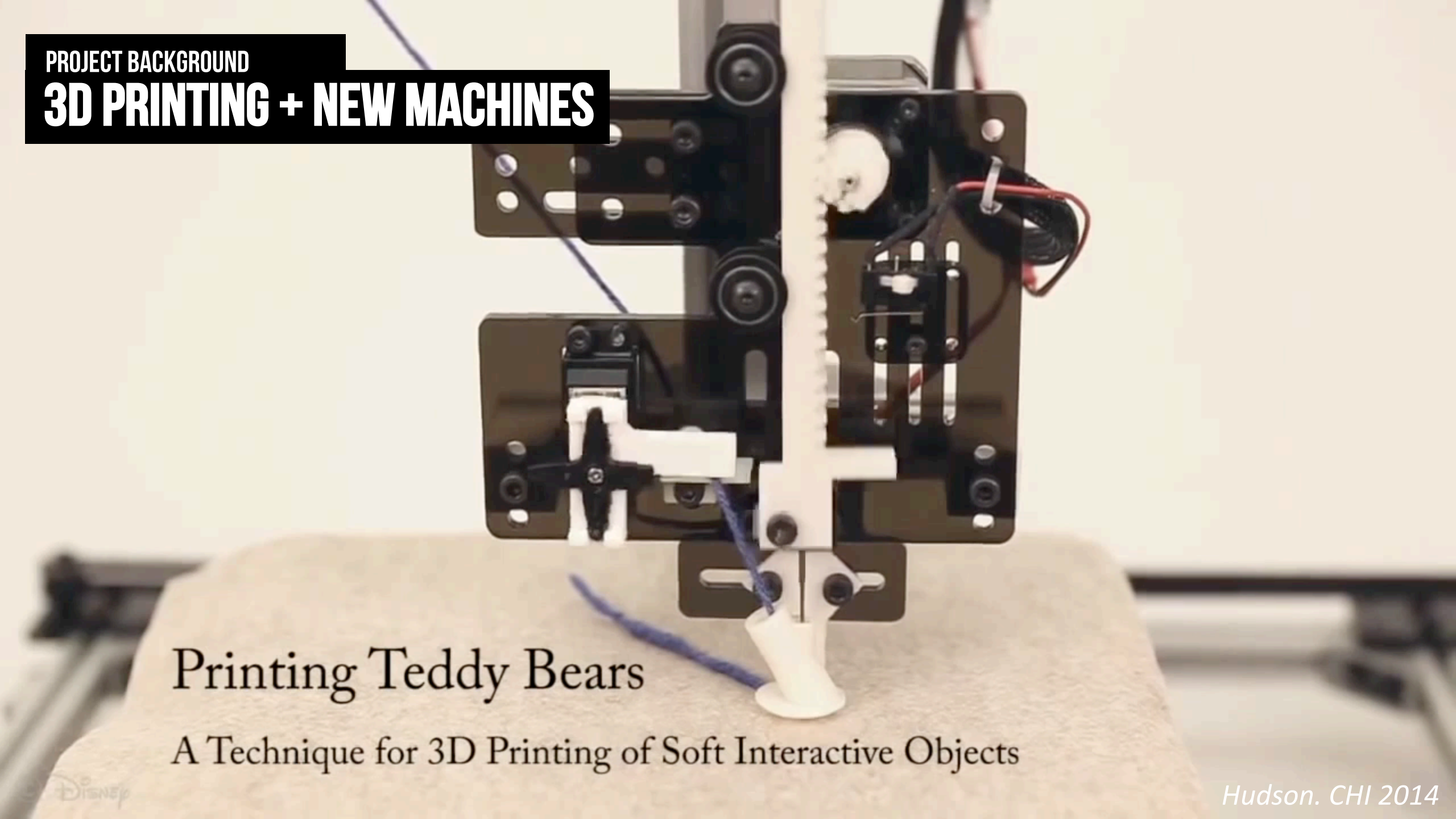
3D PRINTING + COMPOUND MATERIALS



He et al. TEI 2017

PROJECT BACKGROUND

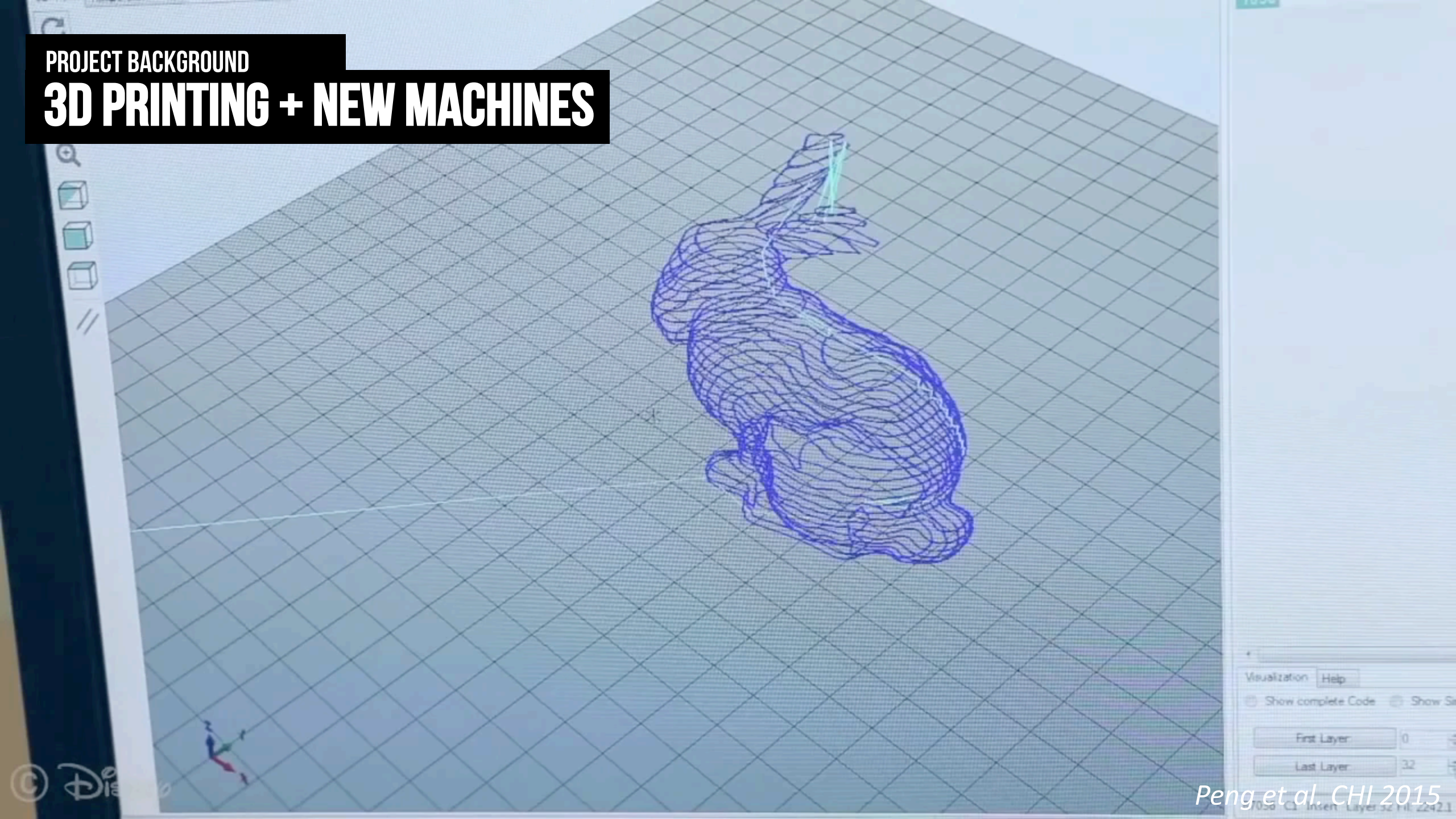
3D PRINTING + NEW MACHINES



Hudson. CHI 2014

PROJECT BACKGROUND

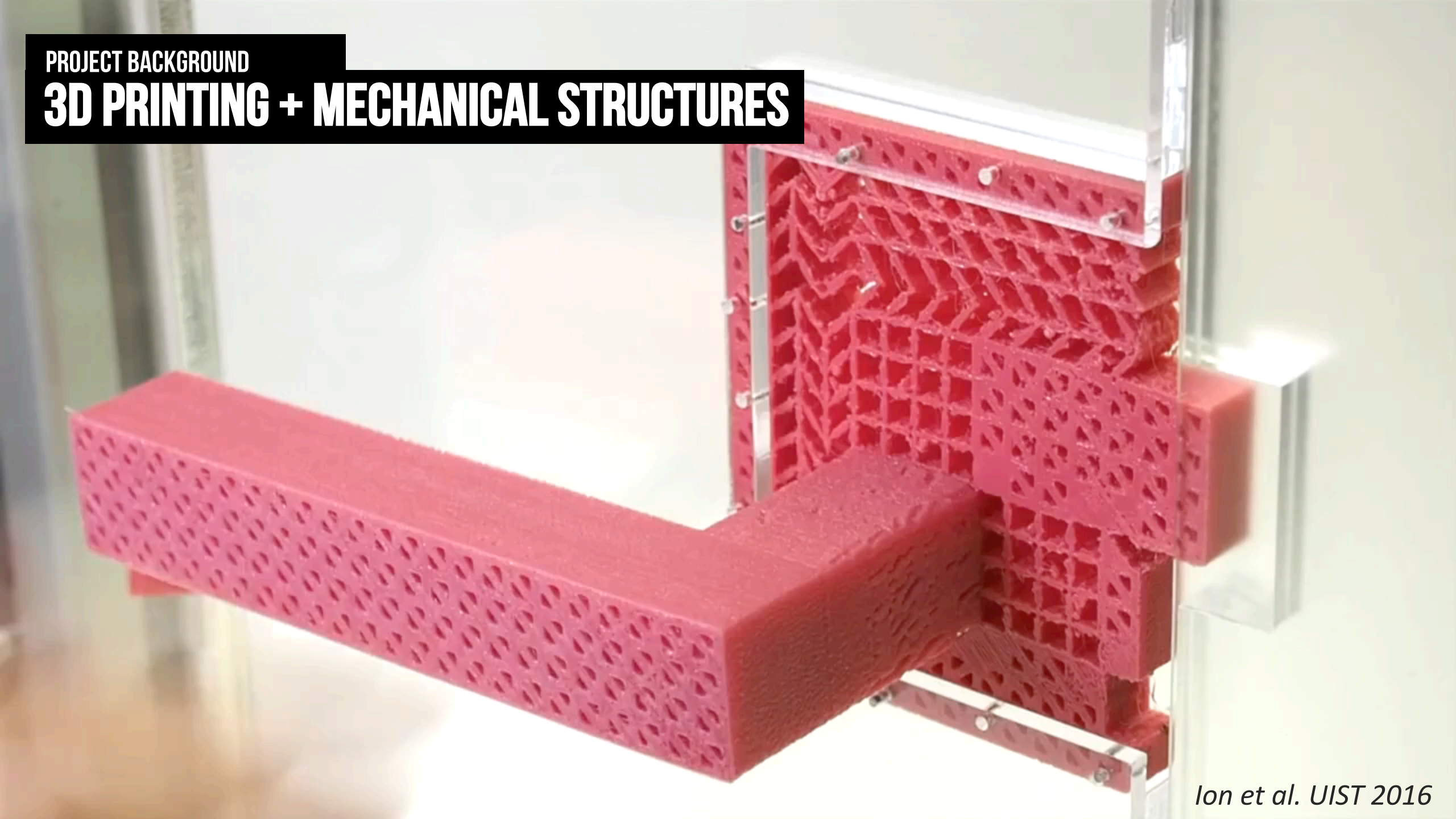
3D PRINTING + NEW MACHINES



Peng et al. CHI 2015

PROJECT BACKGROUND

3D PRINTING + MECHANICAL STRUCTURES

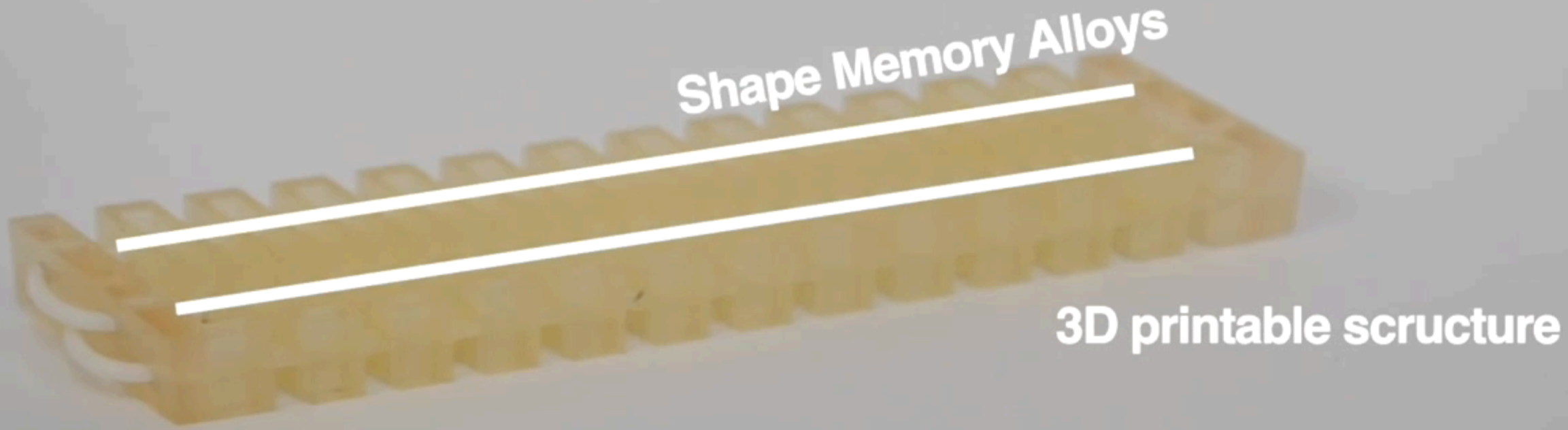


Ion et al. UIST 2016

PROJECT BACKGROUND

3D PRINTING + MECHANICAL STRUCTURES

shape memory alloys and 3D printable stracture
that is flexible in one deformation mode
but stiff in the other deformation modes.

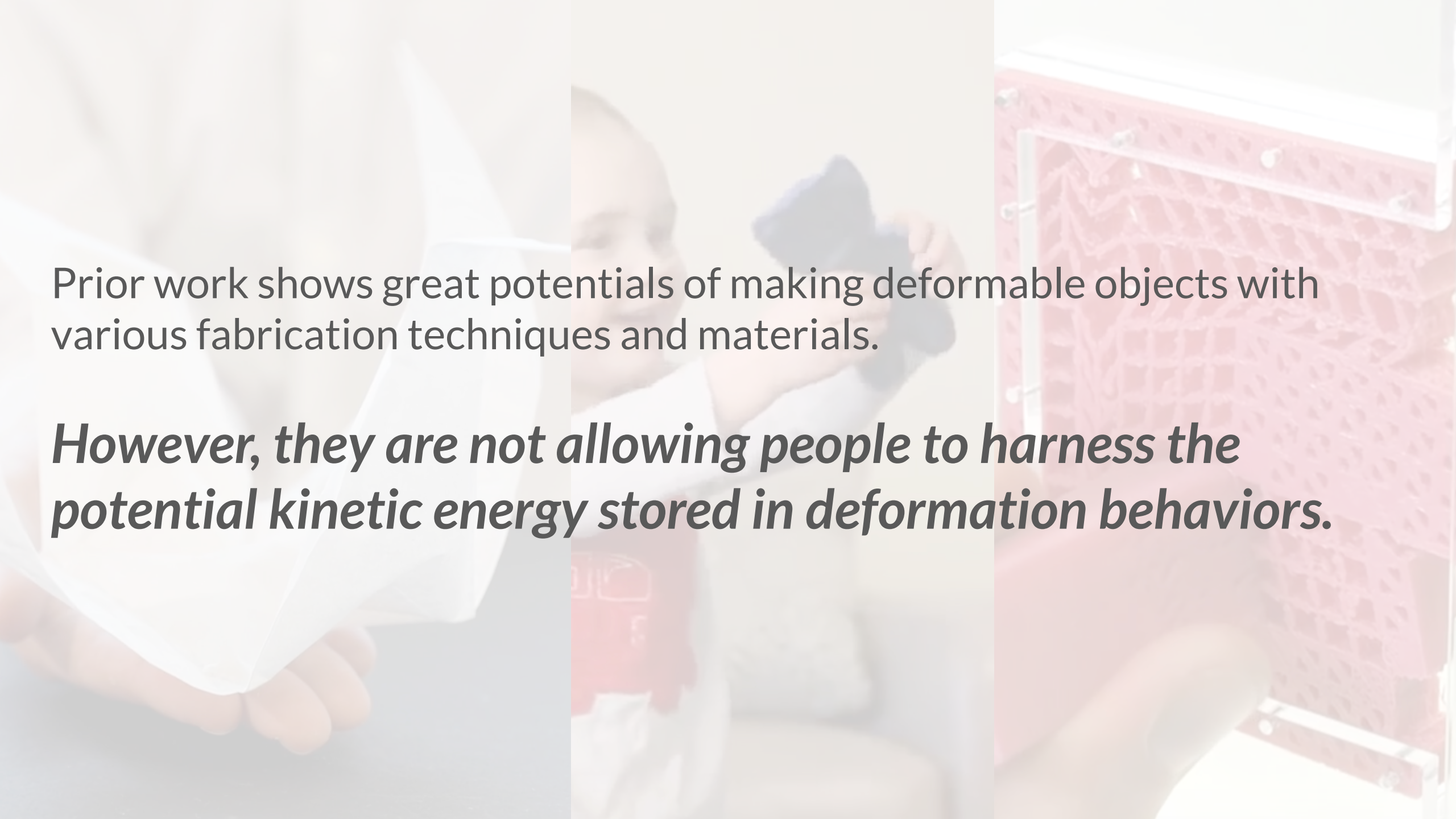


Iwafune et al. SIGGRAPH 2016

PROJECT BACKGROUND

3D PRINTING + MECHANICAL STRUCTURES

Sugihara et al. YouFab Global Creative Awards 2016



Prior work shows great potentials of making deformable objects with various fabrication techniques and materials.

However, they are not allowing people to harness the potential kinetic energy stored in deformation behaviors.

COMPUTATIONAL FABRICATION

PROJECT ONDULÉ

We are using springs…

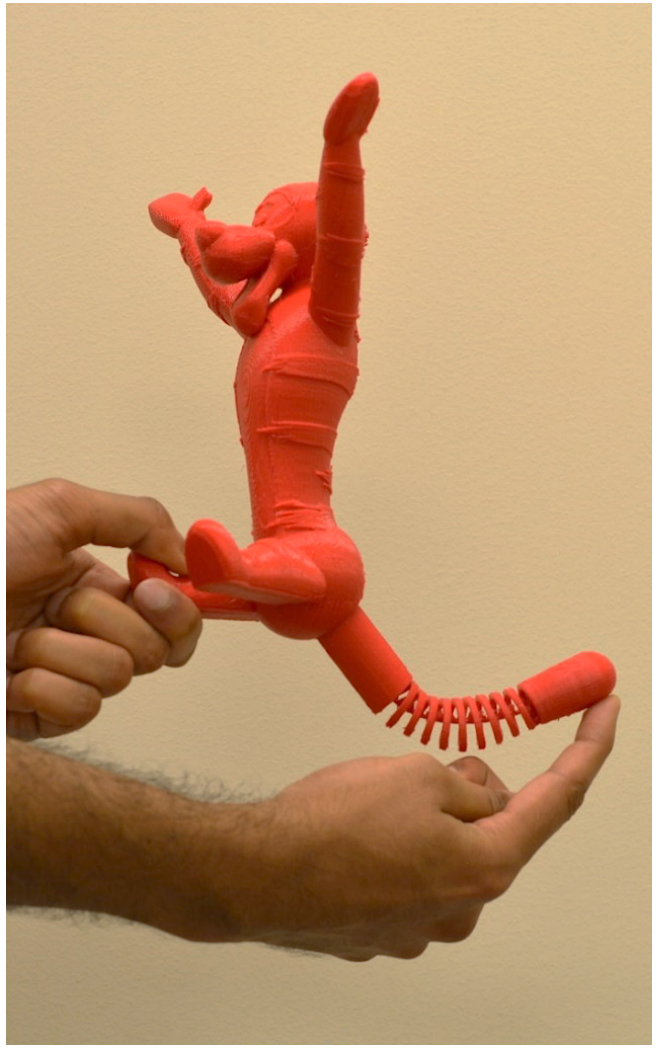
Widely used mechanical mechanisms but not in 3D Printing

Offer expressive deformation behaviors

Lock and release potential kinetic energy

COMPUTATIONAL FABRICATION

PROJECT ONDULÉ



How can we…

enable designers to rapidly build, simulate, and fabricate deformable 3D-printable objects with embedded mechanical springs?

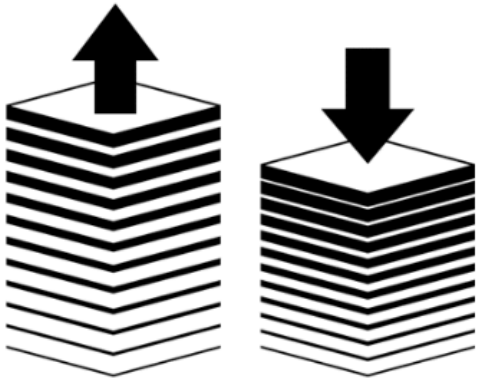
Design Space

Design Tool

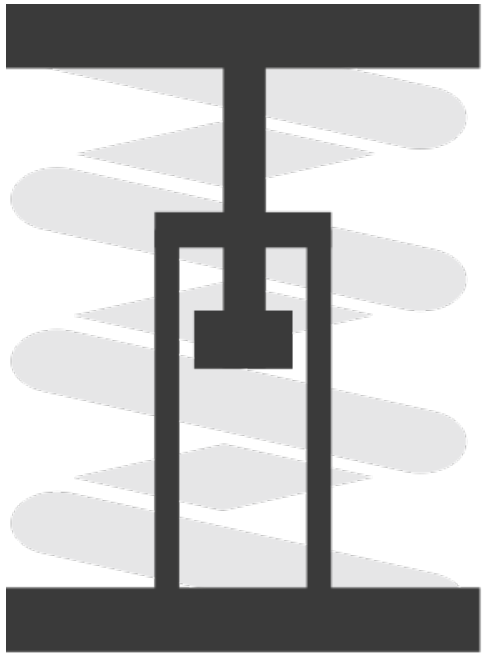
Applications

PROJECT ONDULÉ

DESIGN SPACE



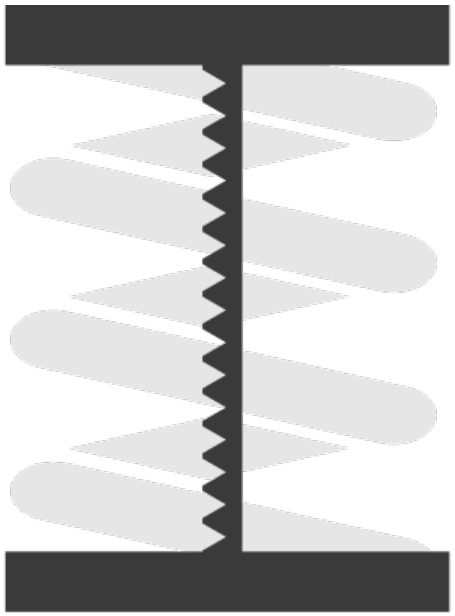
Stretching &
Compressing



PROJECT ONDULÉ

DESIGN SPACE

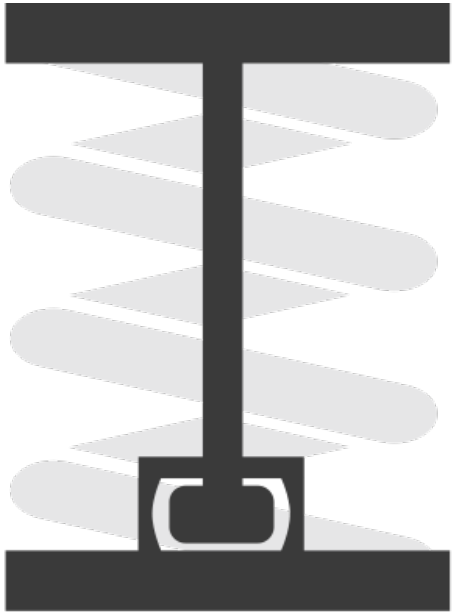
Bending

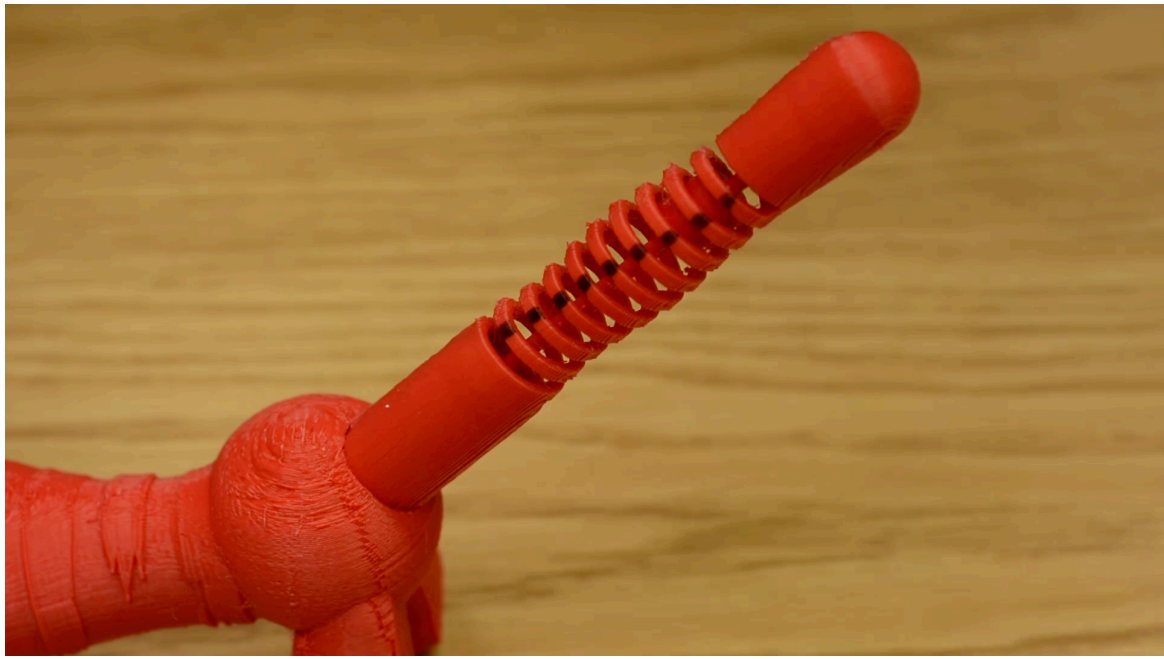


PROJECT ONDULÉ

DESIGN SPACE

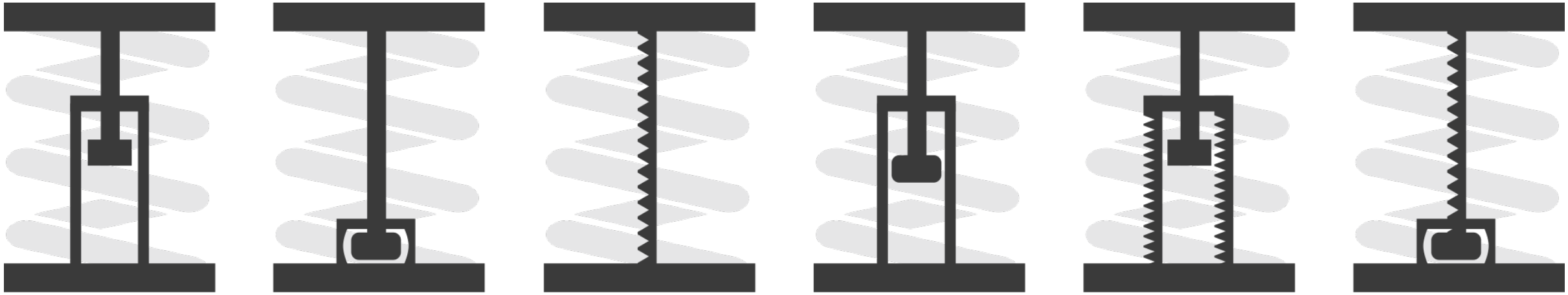
Twisting





PROJECT ONDULÉ

DESIGN SPACE



Linear
(stretch & compress)

Twist

Bend

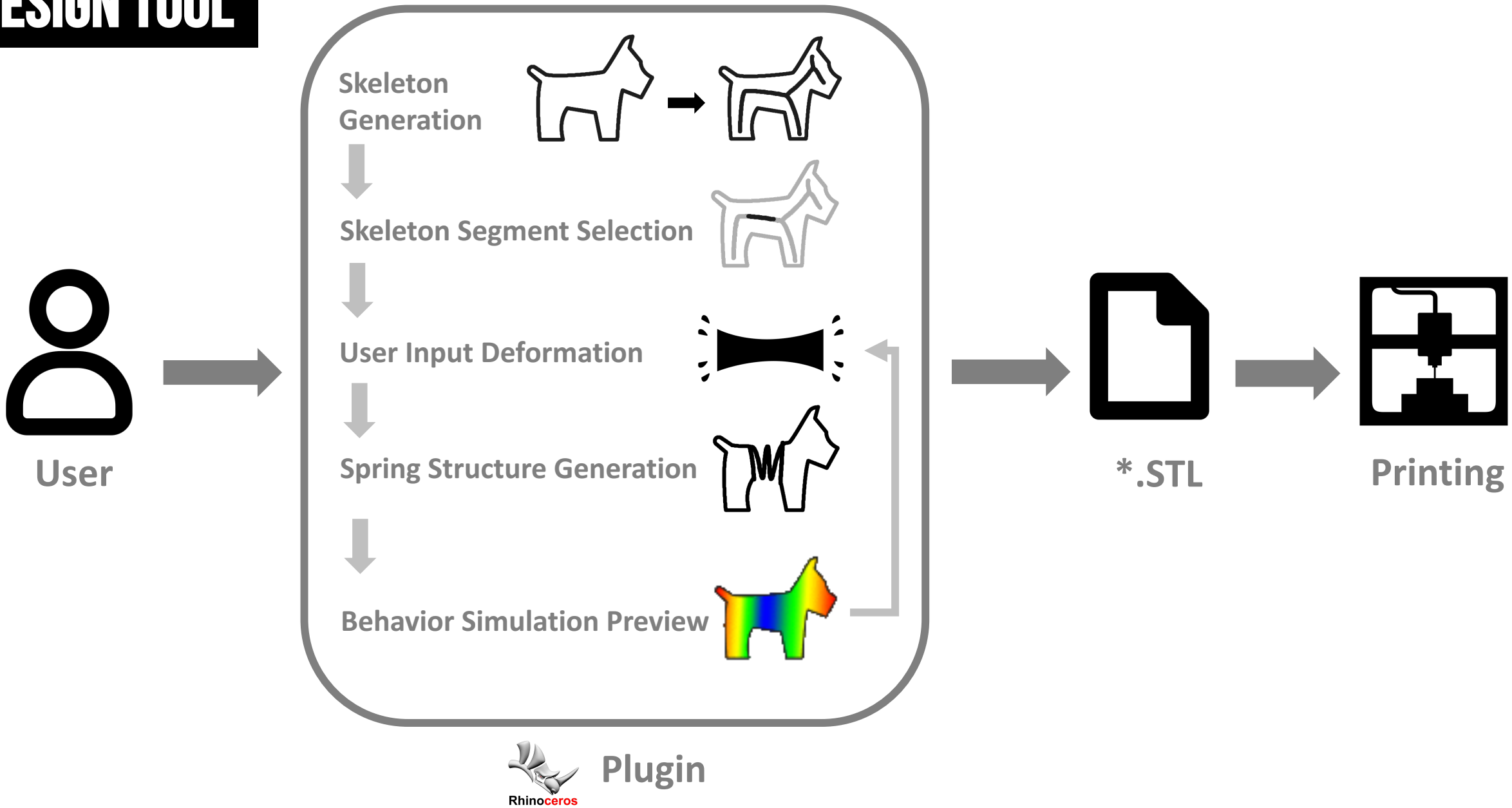
Linear + Twist

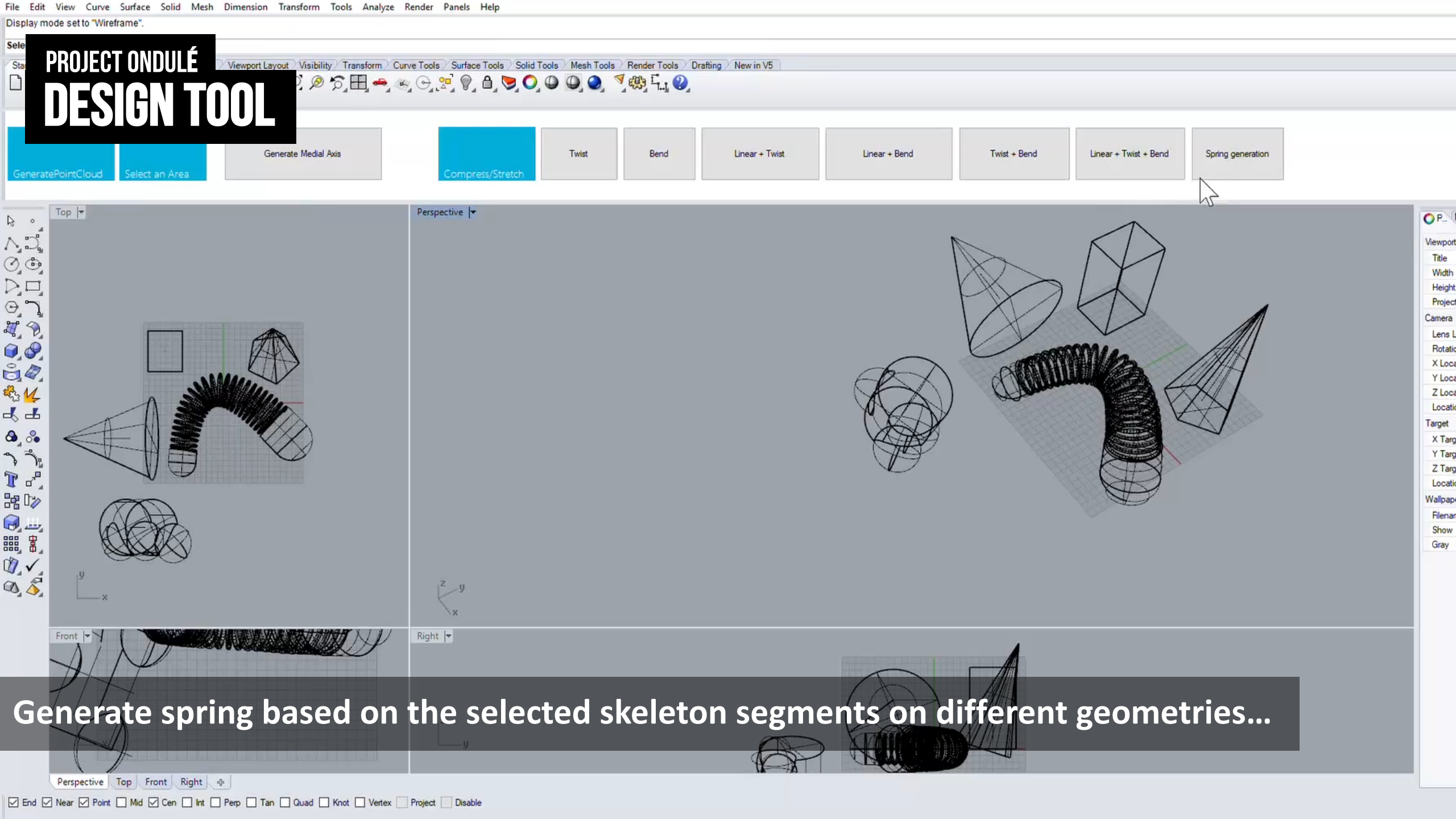
Linear + Bend

Twist + Bend

PROJECT ONDULÉ

DESIGN TOOL




PROJECT ONDULÉ
DESIGN TOOL
GeneratePointCloud
Select an Area
Generate Medial Axis
Compress/Stretch
Twist
Bend
Linear + Twist
Linear + Bend
Twist + Bend
Linear + Twist + Bend
Spring generation
Top
Perspective
Front
Right
Generate spring based on the selected skeleton segments on different geometries…

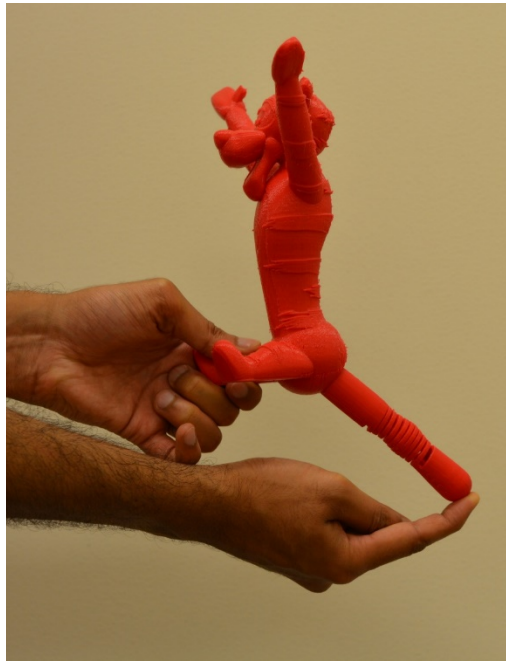
PROJECT ONDULÉ

EXAMPLE DEFORMATIONS

INTERACTIVE TOYS

DESIGN #1: BEND ONLY

Helical spring with embedded flexible sawtooth backbone



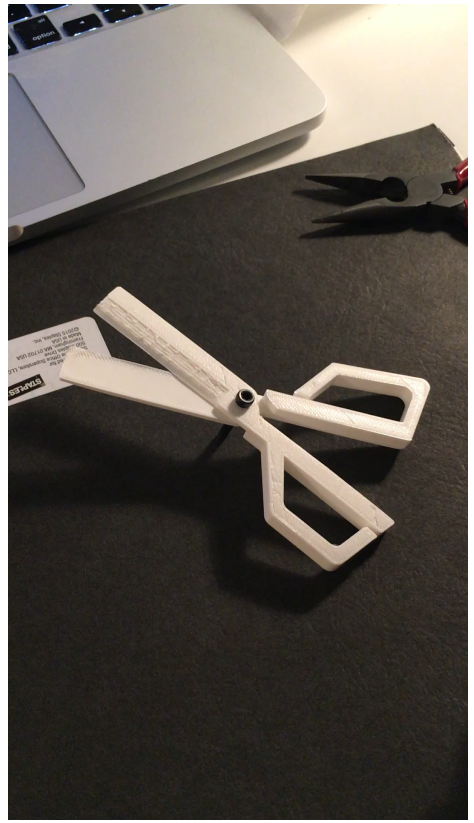
DESIGN #2: LINEAR ONLY

Helical spring with a prismatic joint

DESIGN #3: TWIST ONLY

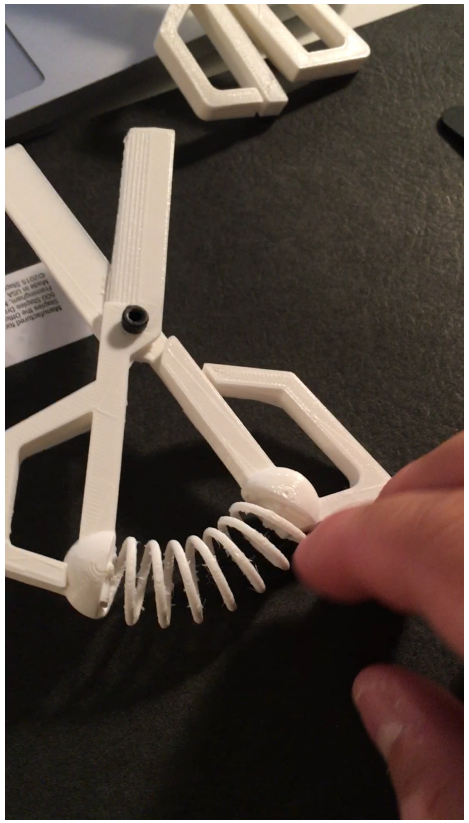
Helical spring with a ring bearing structure

ACCESSIBILITY APPLICATIONS



TRADITIONAL SCISSORS

Requires fine motor abilities

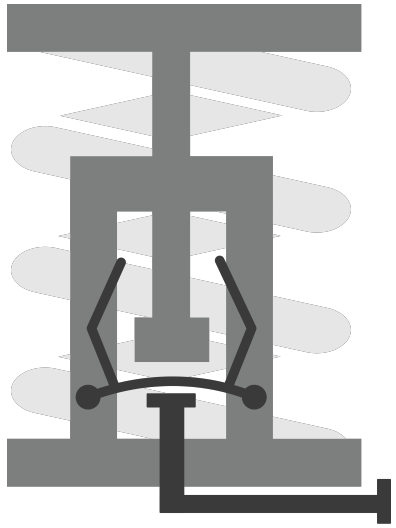


SPRING SCISSORS

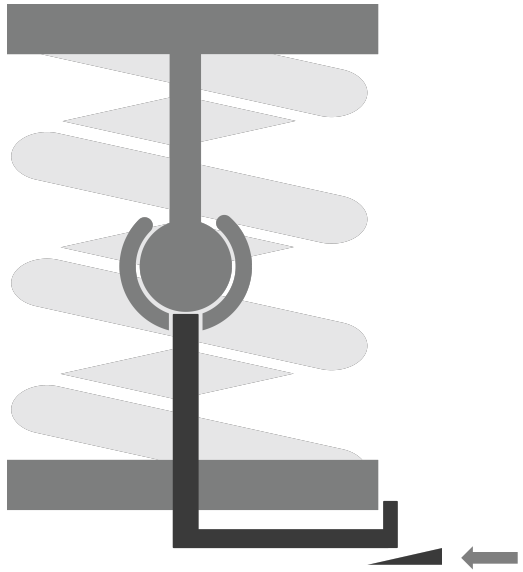
Spring automatically reopens scissors after a cut

PROJECT ONDULÉ

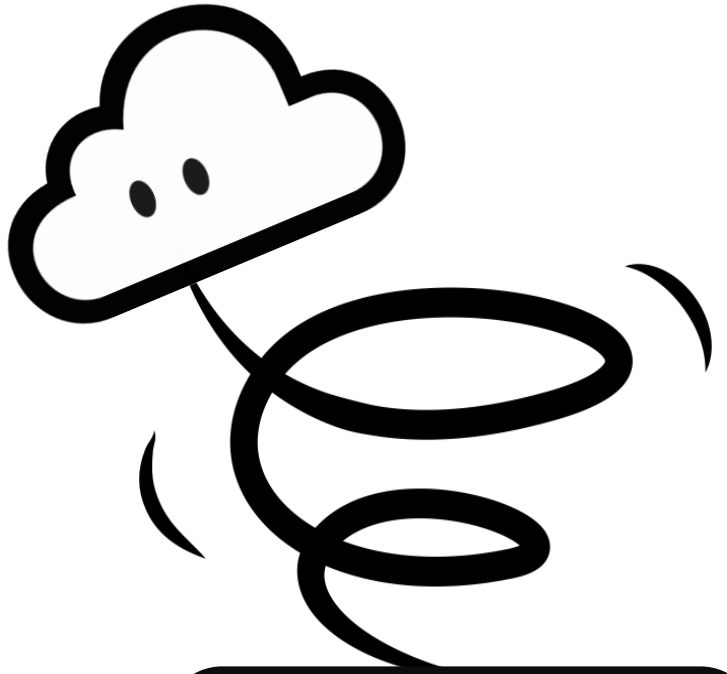
FUTURE WORK



Bi-stable Spring Lock



Ball Joint Lock

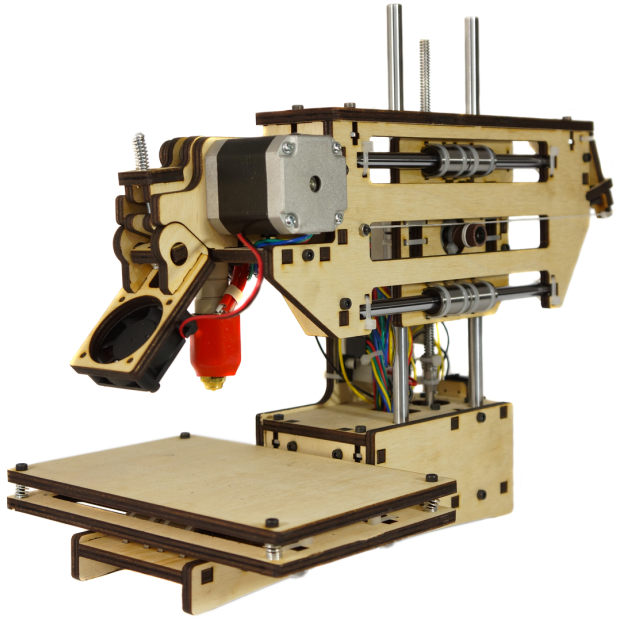


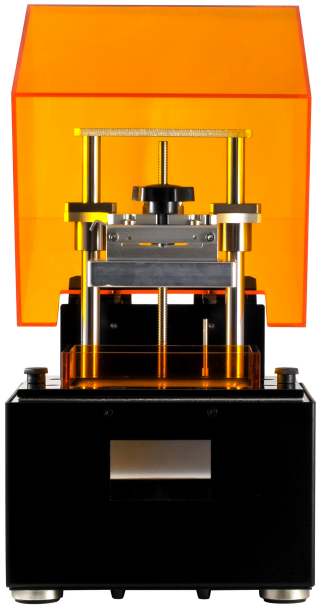
INTRODUCING MECHANICAL LOCKS

ENERGY RELATED APPLICATIONS

PROJECT ONDULÉ

FUTURE WORK





3D printers with different resolutions and manufacturing processes

Different materials

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