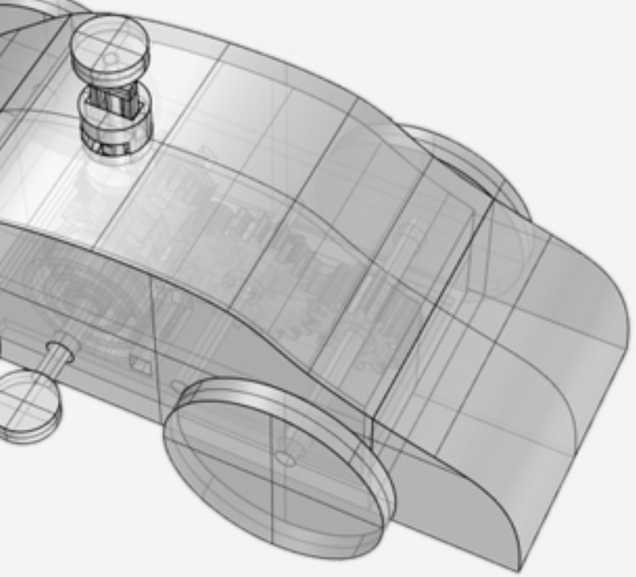


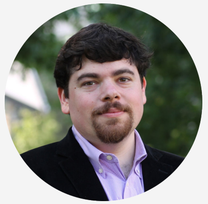
Kinergy

Creating 3D Printable Motion using Embedded Kinetic Energy


Liang He


Xia Su


Huaishu Peng


Jeff Lipton


Jon Froehlich

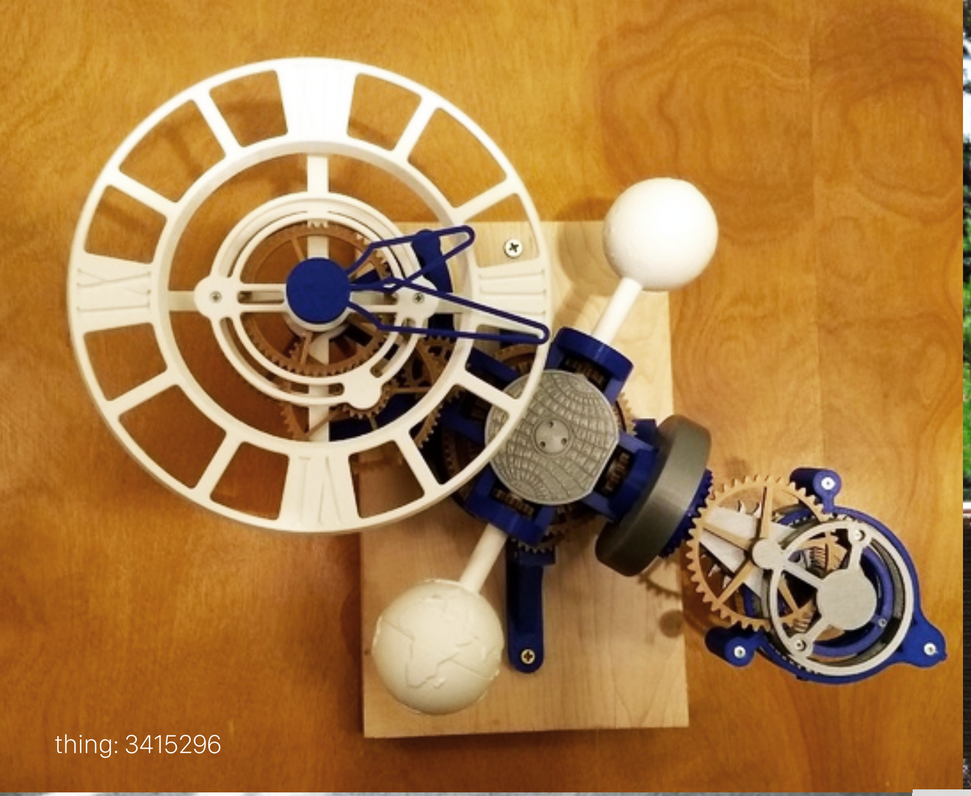
MAKEABILITY LAB

PAUL G. ALLEN SCHOOL OF COMPUTER SCIENCE & ENGINEERING

MECHANICAL ENGINEERING UNIVERSITY of WASHINGTON

SMALL _ARTIFACTS LAB;

UIST 2022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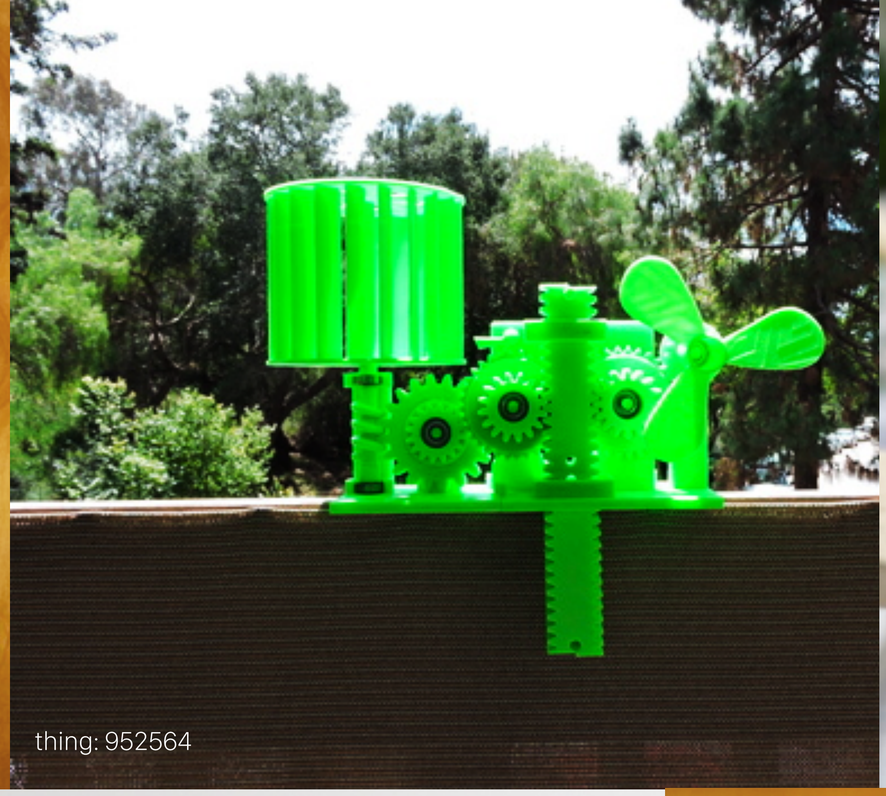
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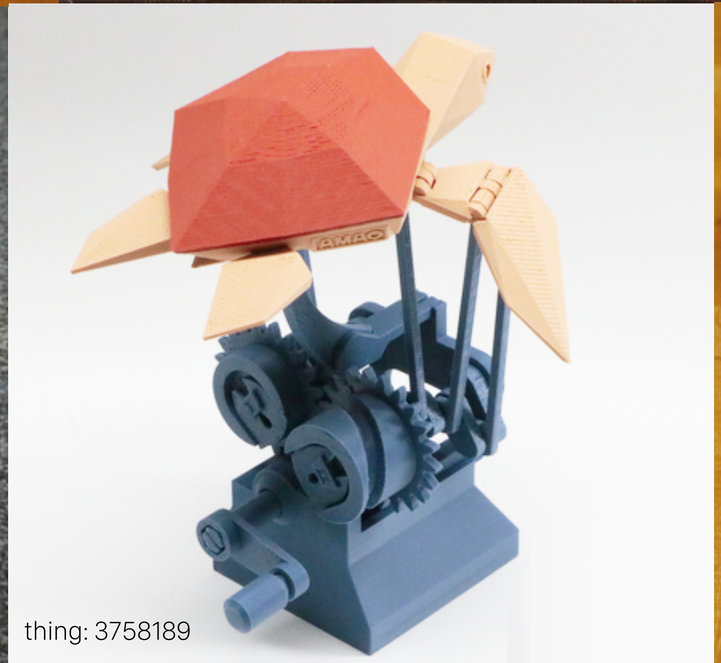
thing: 3928677


thing: 4822059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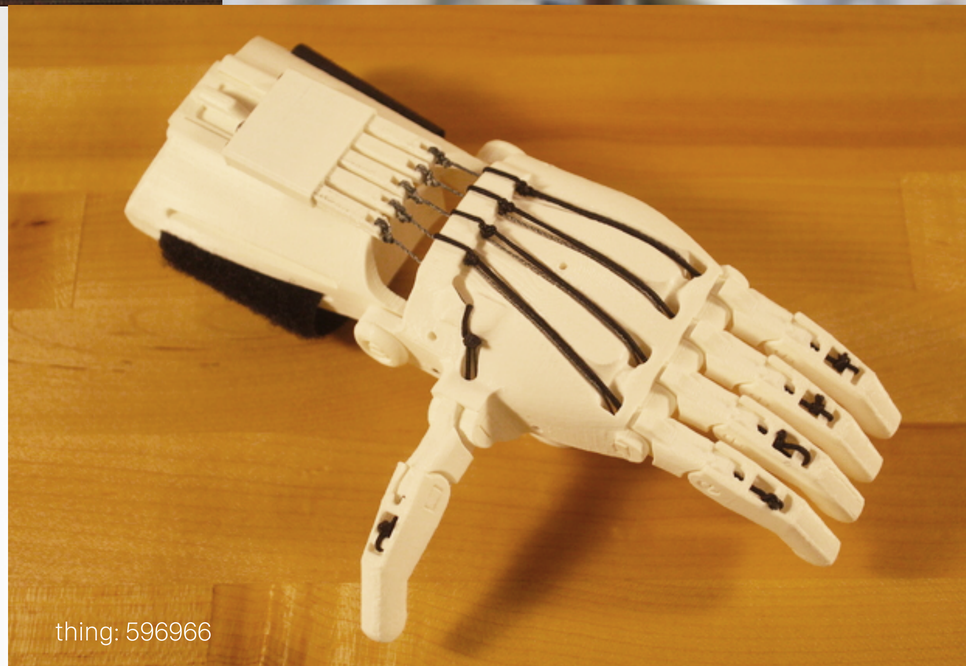

thing: 596966

Autodesk AutoCAD 2016 - STUDENT VERSION new gear.dwg

Type a keyword or phrase | Sign In

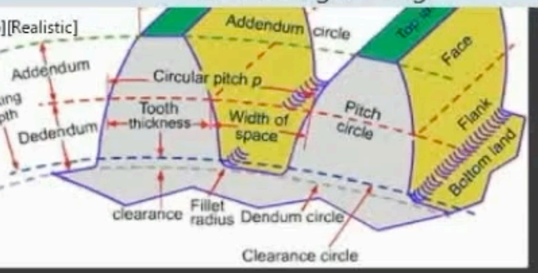
Home | Solid | Surface | Mesh | Visualize | Parametric | Insert | Annotate | View | Manage | Output | Add-ins | A360 | Express Tools | Featured Apps | BIM 360 | Performance

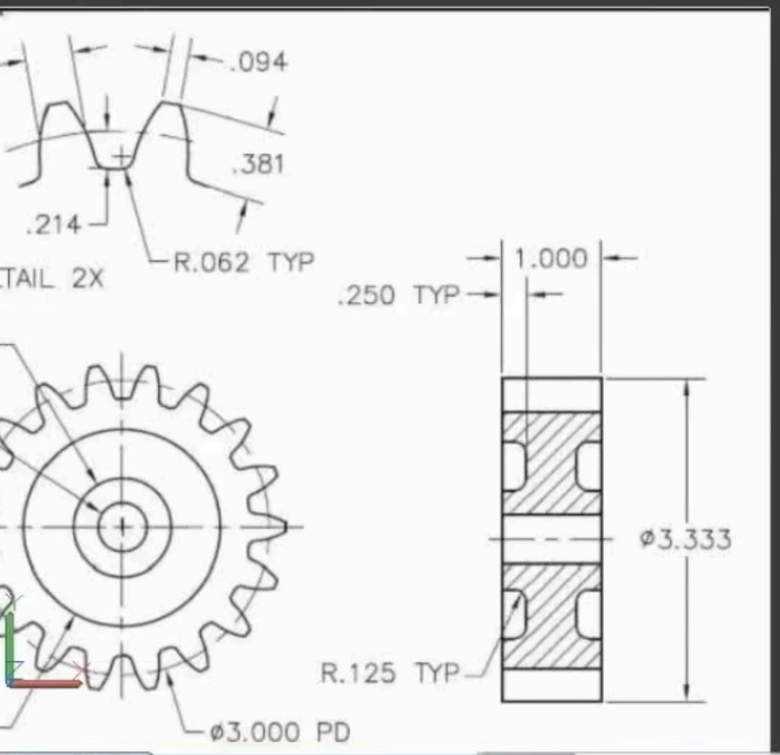
Extrude | Polysolid | Presspull | Smooth Object | Section Plane | Realistic | Unsaved View | Unnamed | Culling | No Filter | Move Gizmo | Layer Properties | Group

Modeling | Mesh | Solid Editing | Draw | Modify | Section | Coordinates | View | Selection | Layers | Groups

art | reference gear* | new gear*

reference gear.dwg





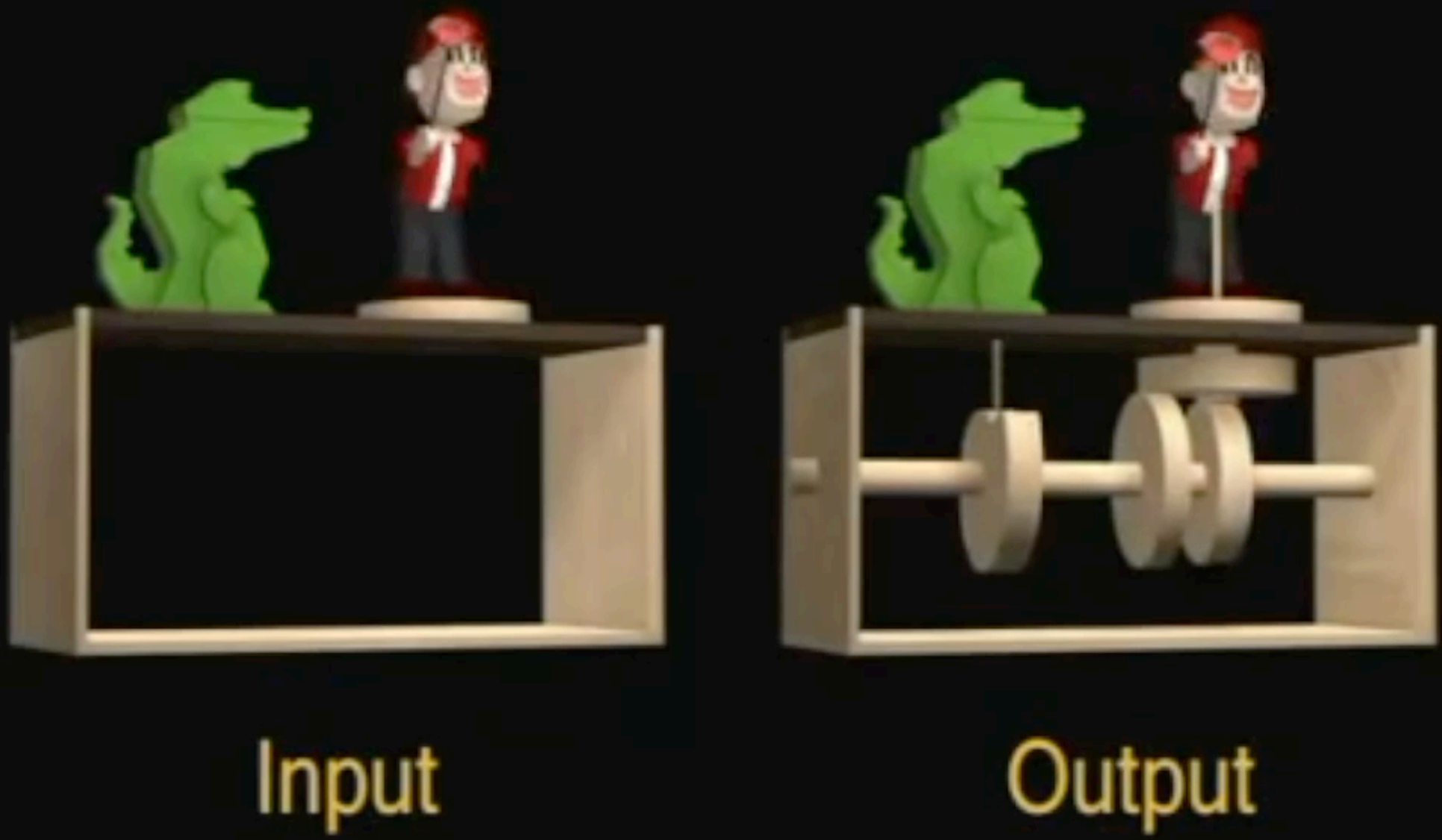
new gear.dwg

A 3D SPUR GEAR TUTORIAL IN AUTOCAD 2016: https://youtu.be/JSYur56ei3g

Type a command

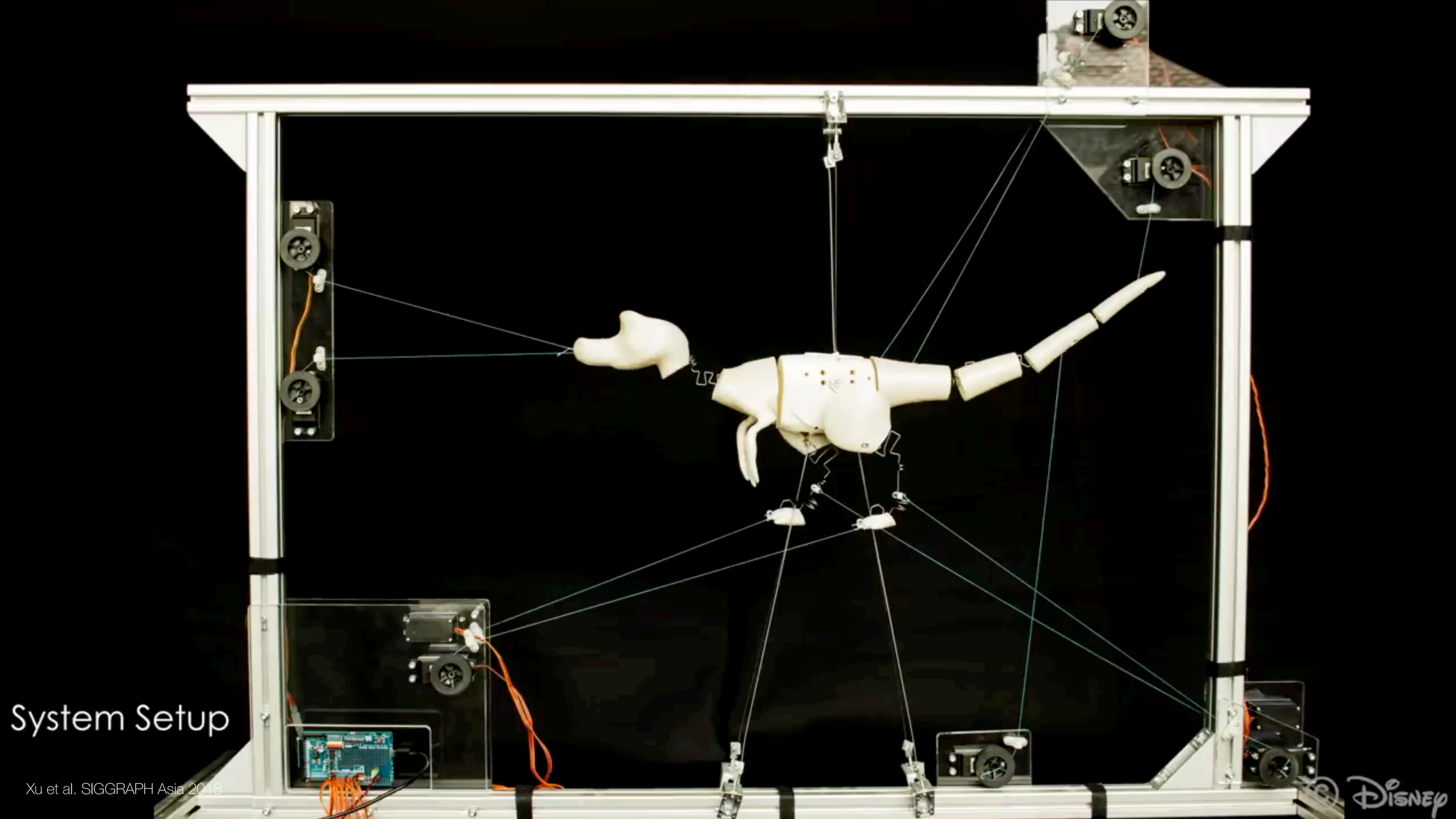
Layout1 | Layout2

Bächer et al. SIGGRAPH 2012



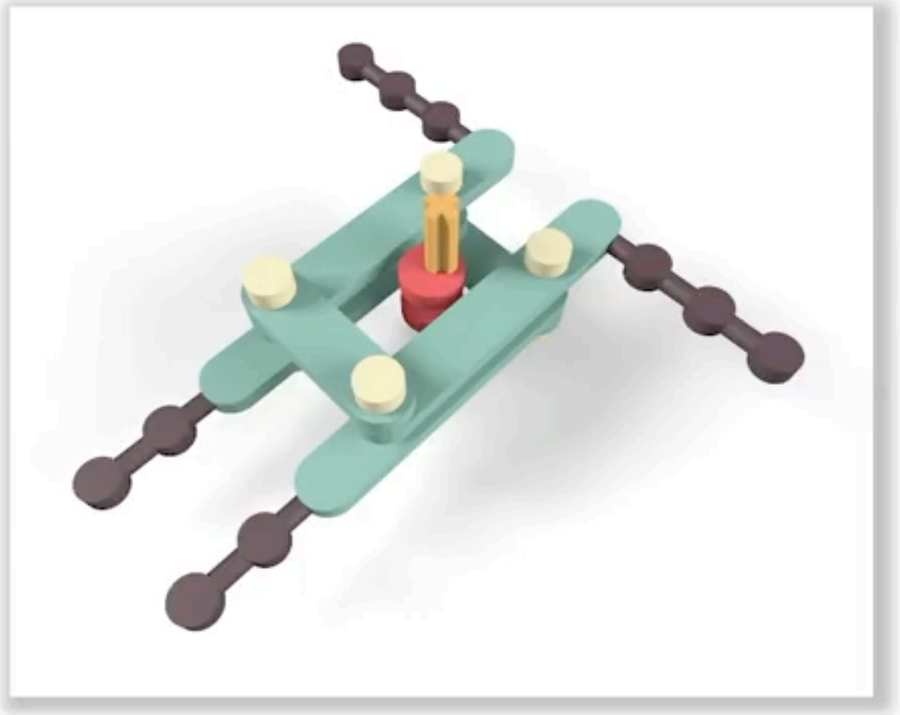
Zhu et al. SIGGRAPH Asia 2012

Song et al. SIGGRAPH Asia 2017



Xu et al. SIGGRAPH Asia 2018

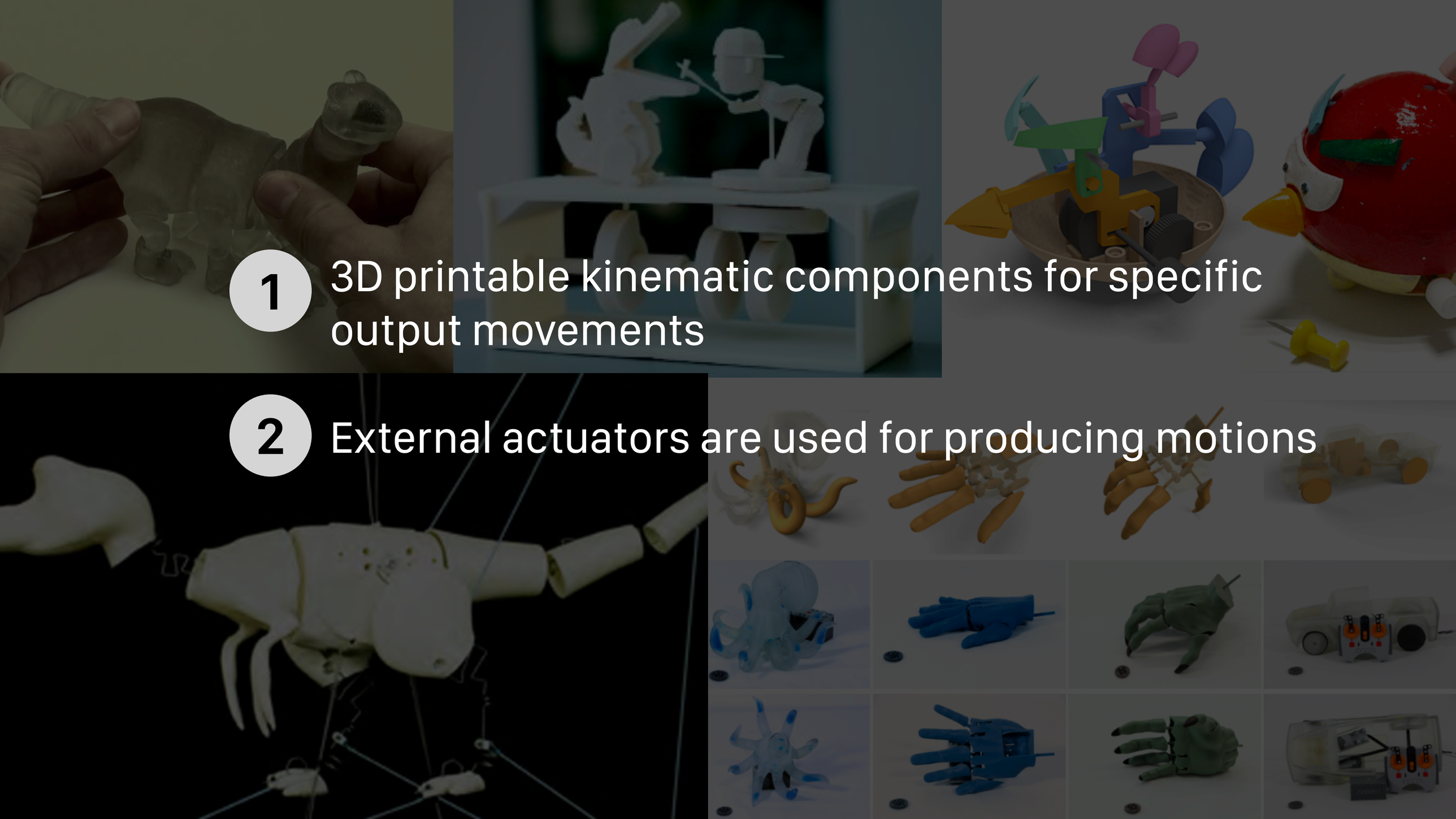
Template



Wind-up toy

Target shape

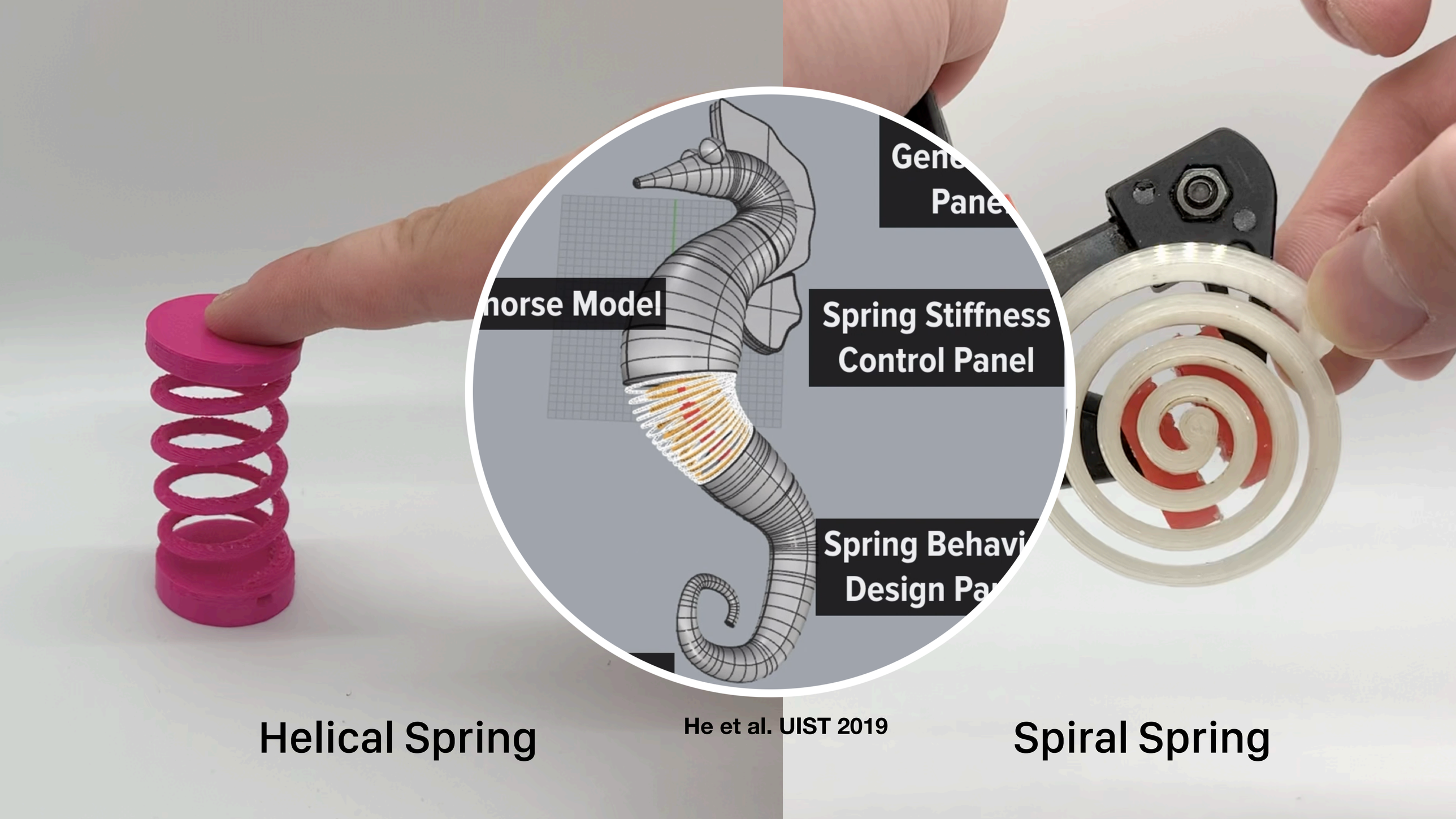
Turtle



1 3D printable kinematic components for specific output movements

2 External actuators are used for producing motions

Can we create custom 3D printable motions using self-contained energy source?



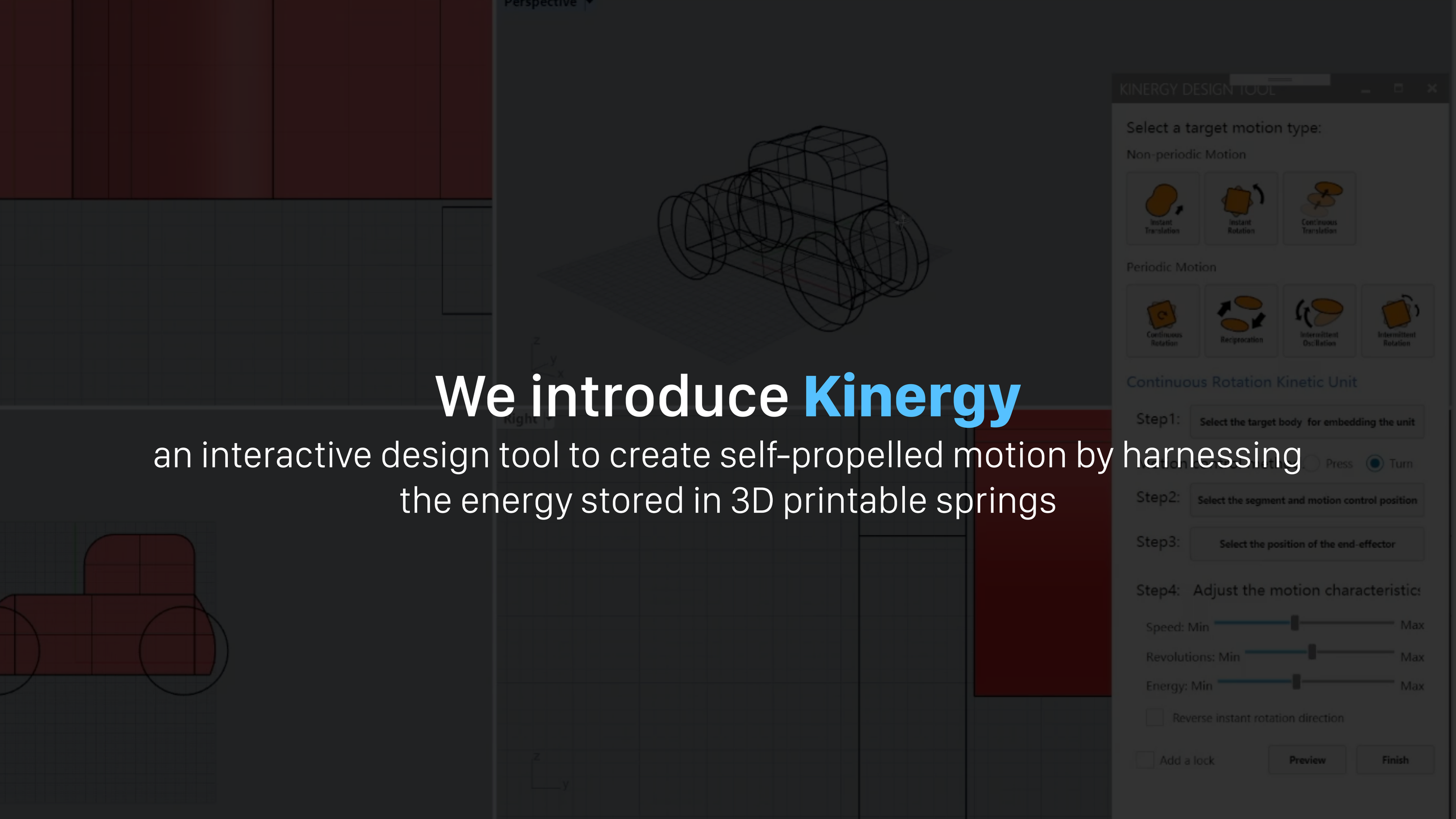
Helical Spring

He et al. UIST 2019

Spiral Spring

Research Questions:

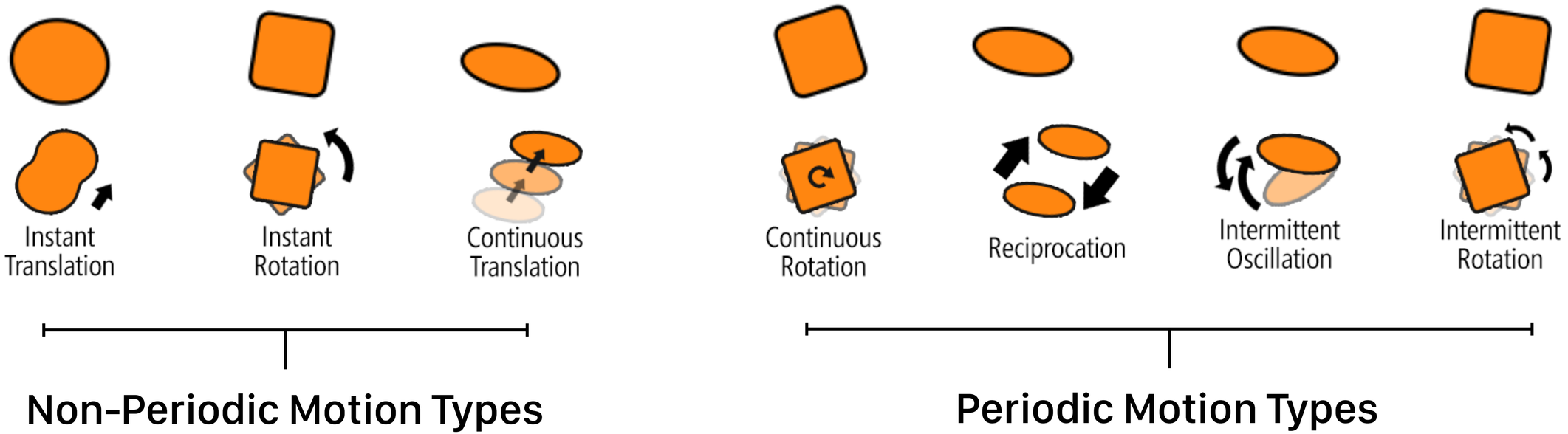
- How to convert spring movements into various controllable output motion behaviors?
- How to lower the barrier for end users to design and control motion for 3D printing?



We introduce Kinergy

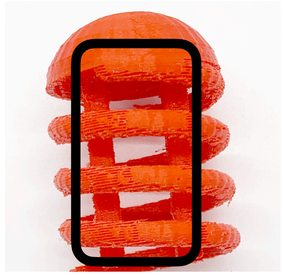
an interactive design tool to create self-propelled motion by harnessing the energy stored in 3D printable springs

To produce controllable output motion, we introduce 3D printable kinetic units—a set of parametrizable designs that use 3D printable springs compliant locks, and transmission mechanisms for

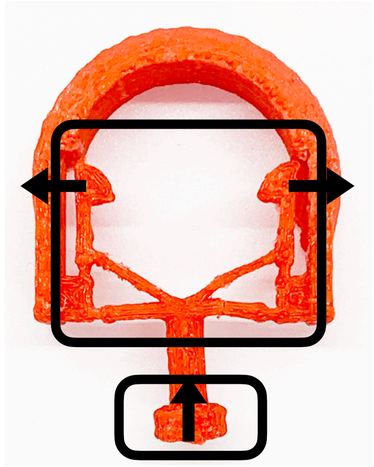


Spring + Compliant Lock Mechanisms

Harnessing the energy stored in springs



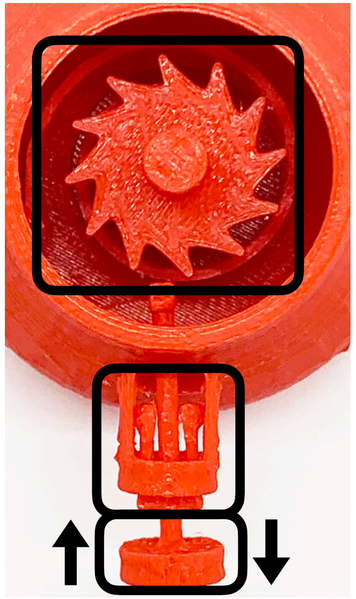
Bars



Button Latch

Helical Spring

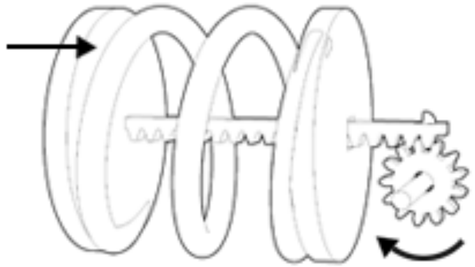
Spiral Spring

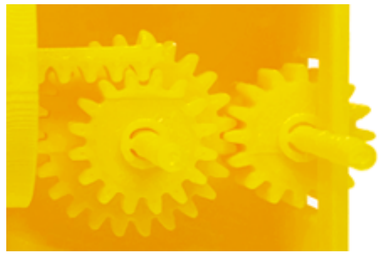


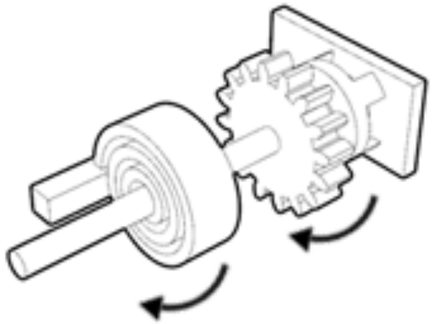
Ratchet Gear

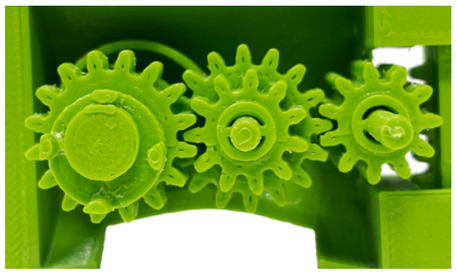
Transmission Mechanism in Periodic Kinetic Units

Translating spring movement into desired output motion

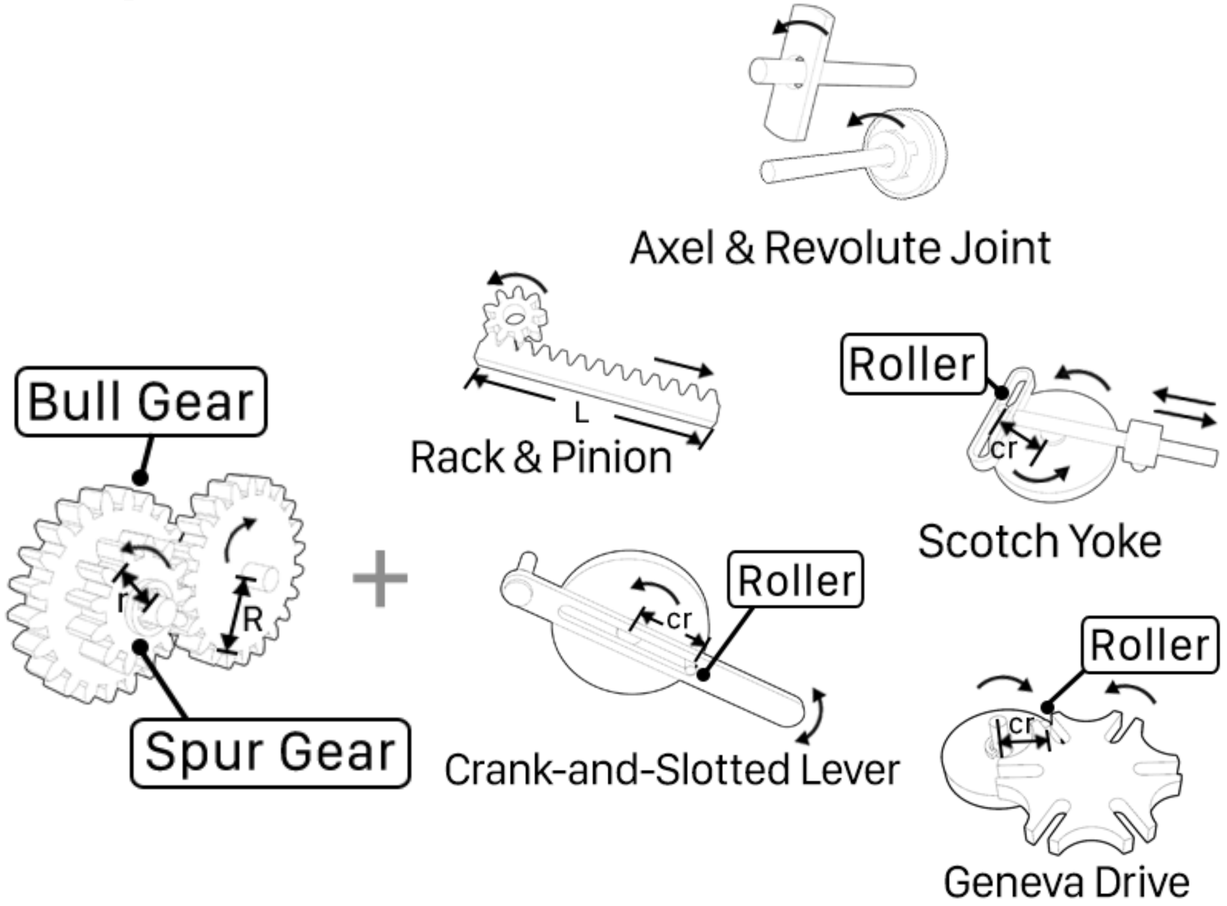






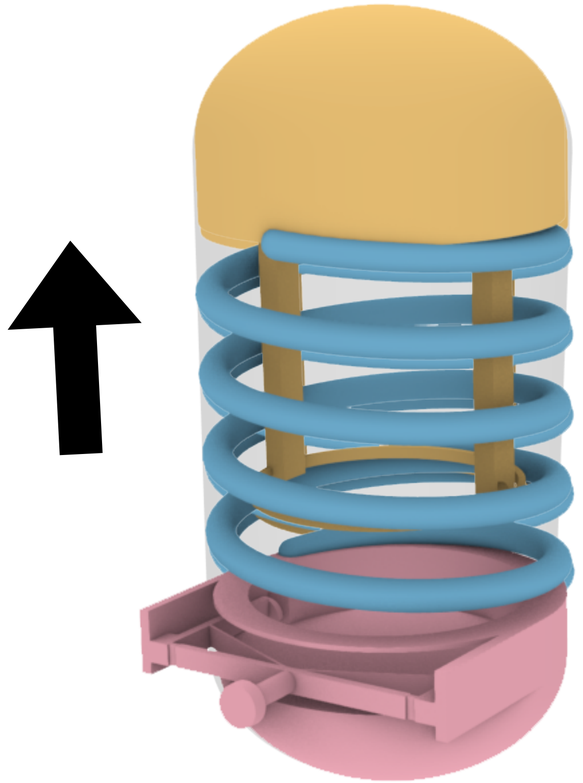


Interfacing Spring & Gear



Gear Trains + Kinematic Elements

Non-Periodic Motion Types



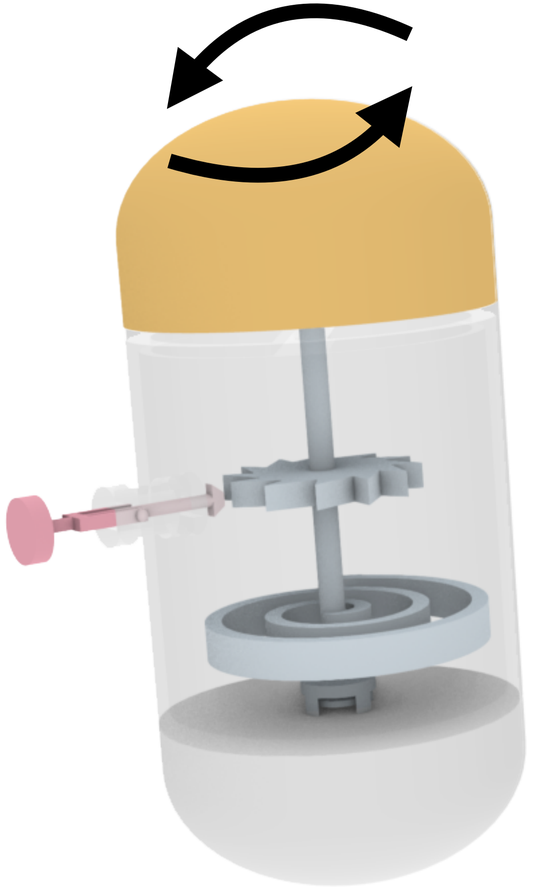
End-Effector

3D Body

Helical Spring

Lock + Stationary Part

Instant
Translation



End-Effector

Spring + Ratchet

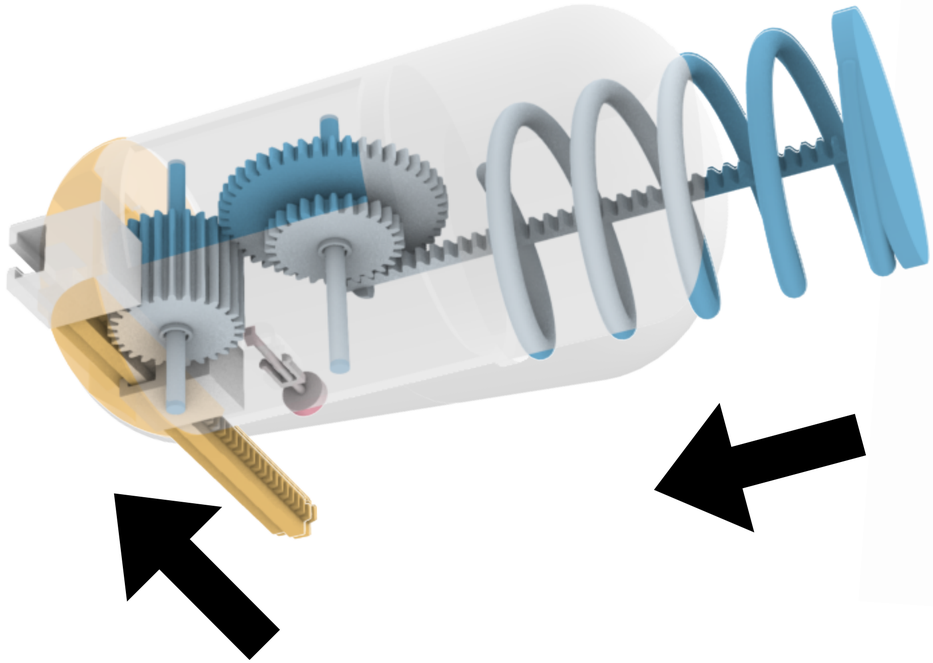
3D Body

Lock + Stationary Part

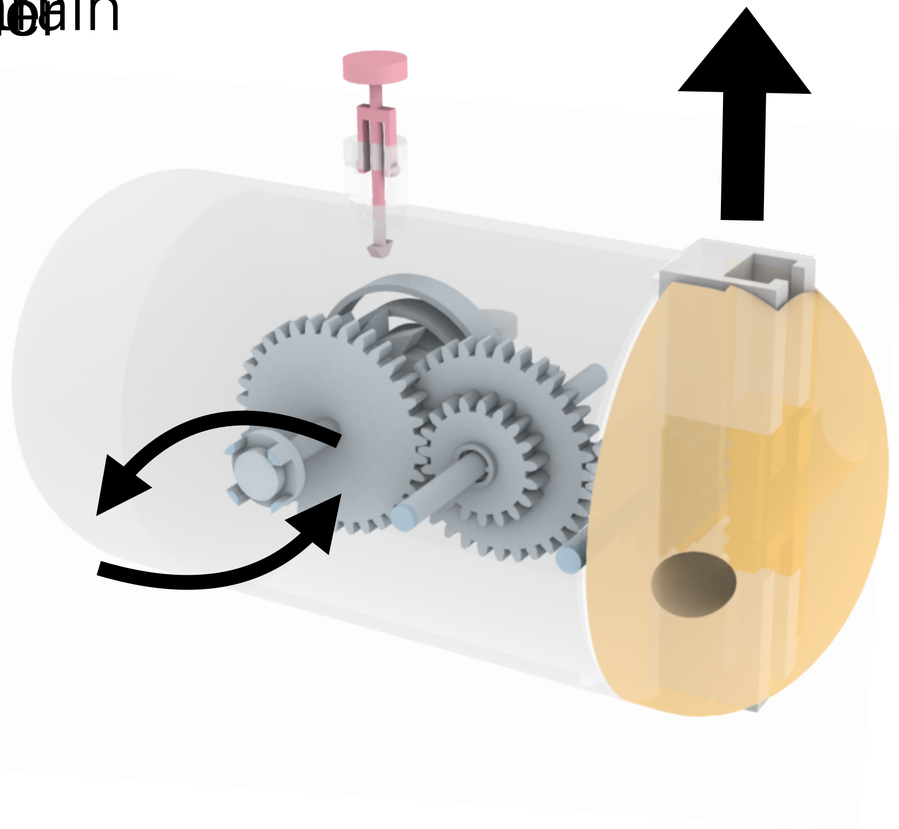
Instant
Rotation

Non-Periodic Motion Types

Continuous Translation



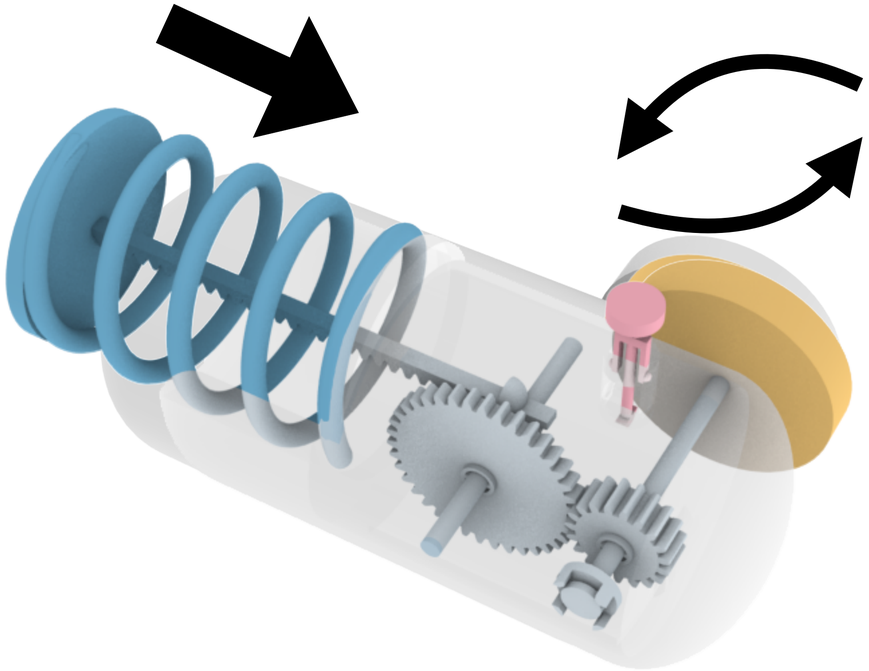
Press Control



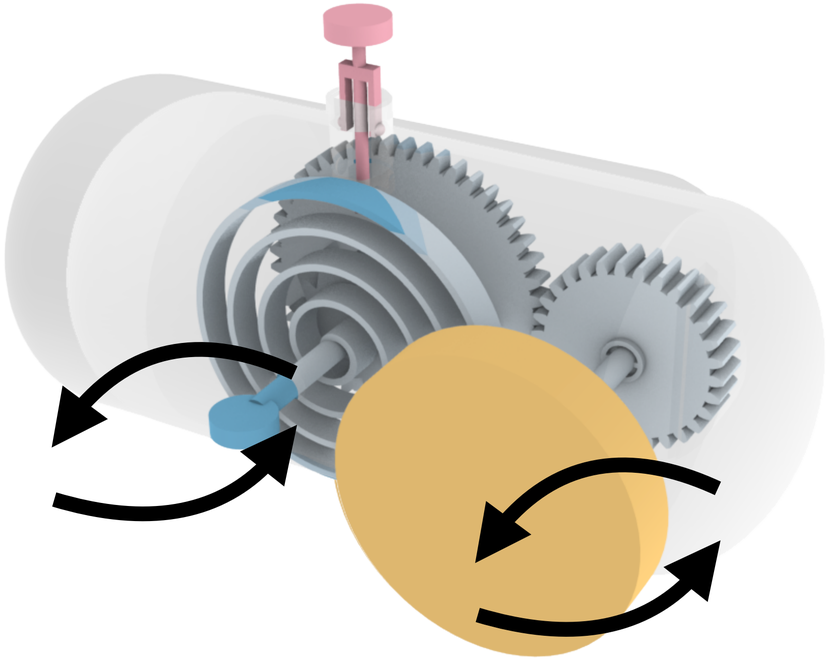
Turn Control

Periodic Motion Types

Continuous Rotation



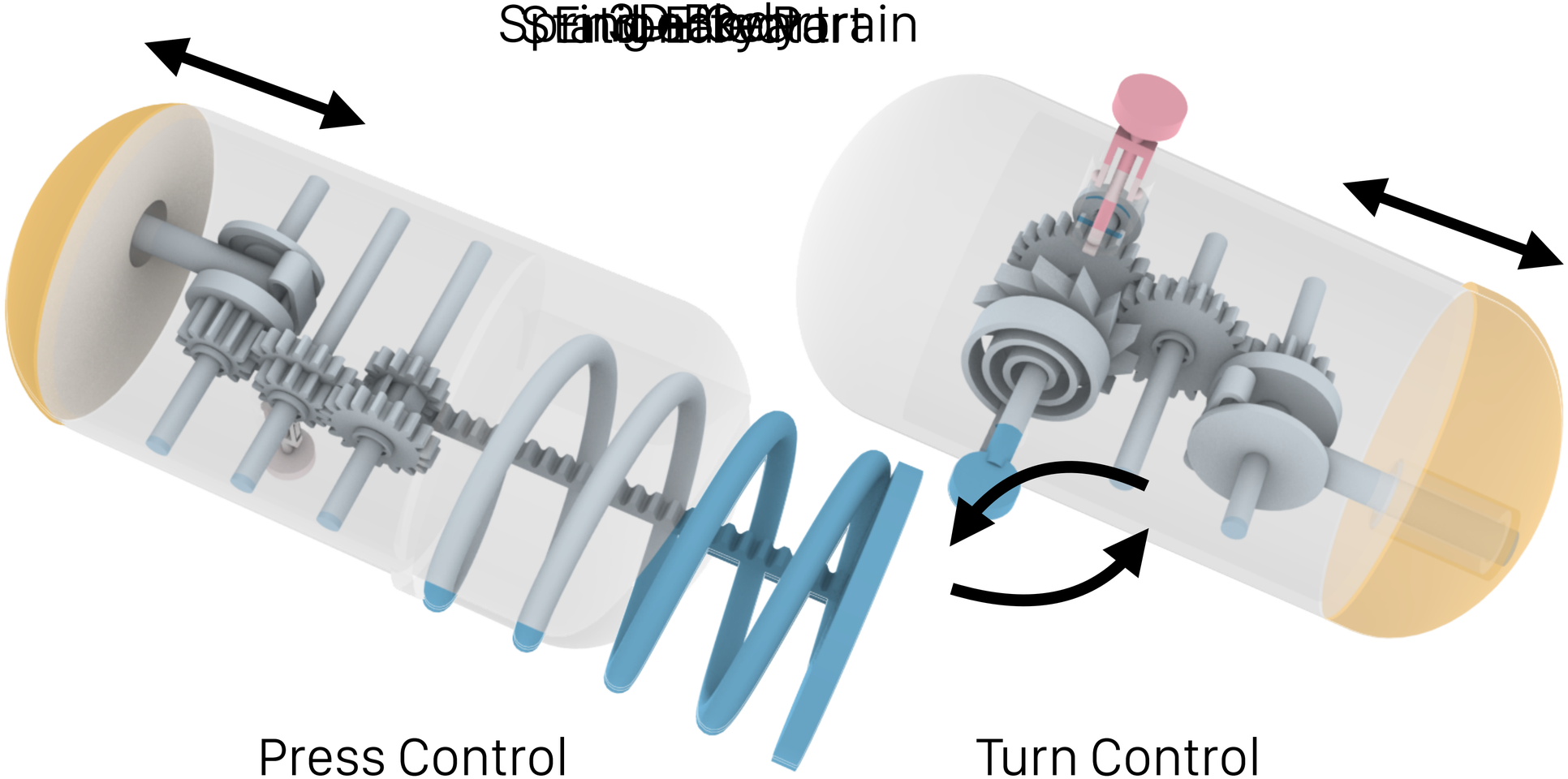
Press Control



Turn Control

Periodic Motion Types

Reciprocation

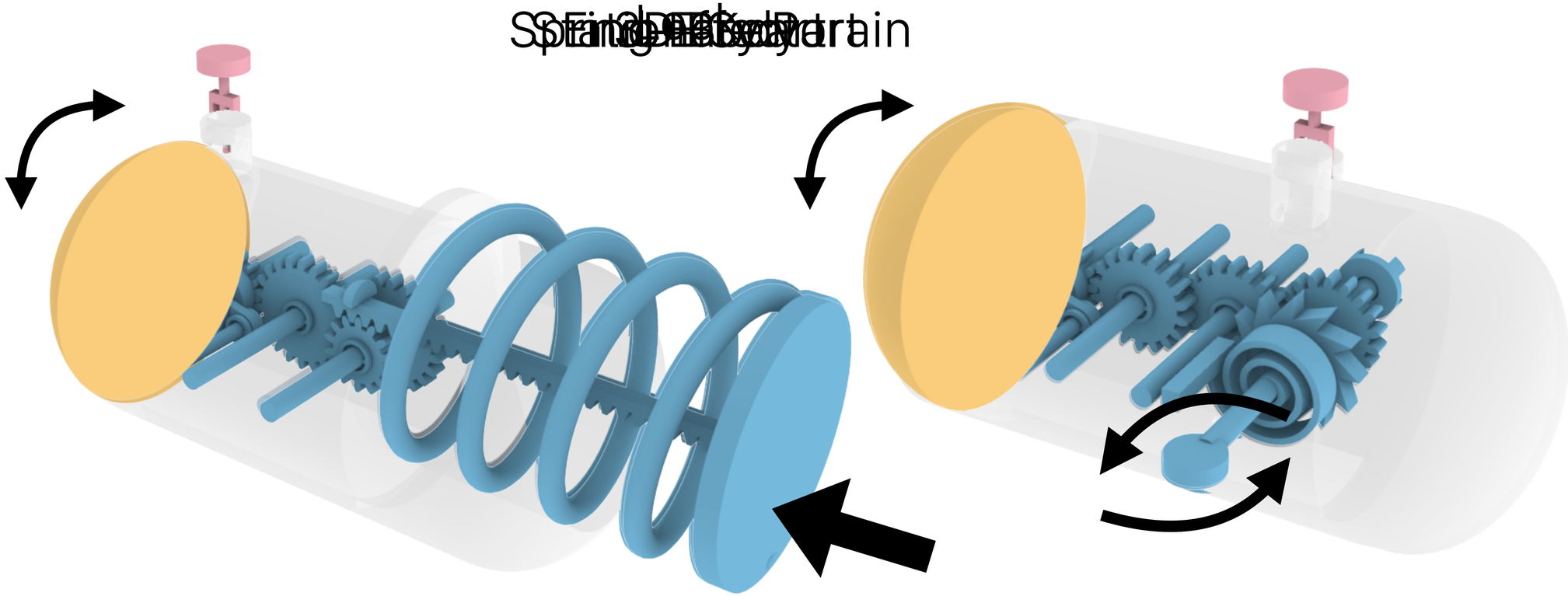


Press Control

Turn Control

Periodic Motion Types

Intermittent
Oscillation

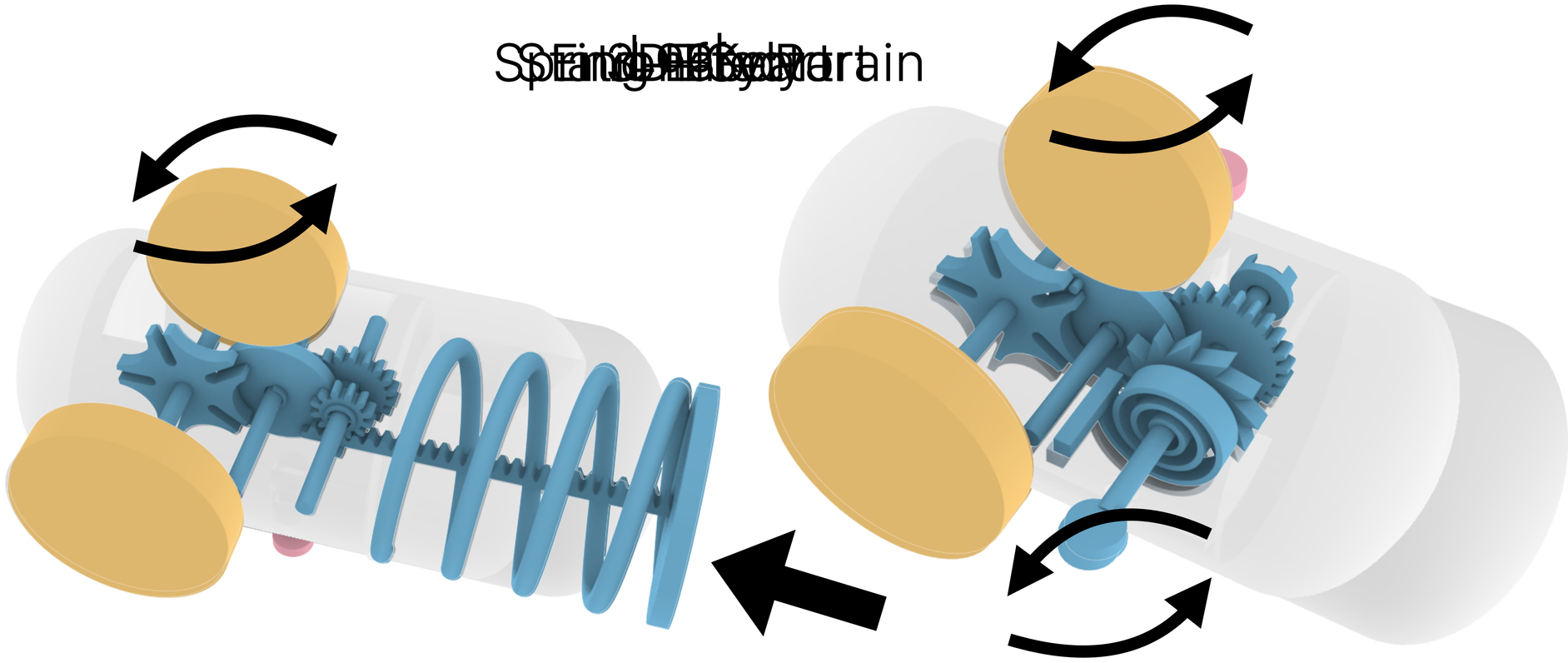


Press Control

Turn Control

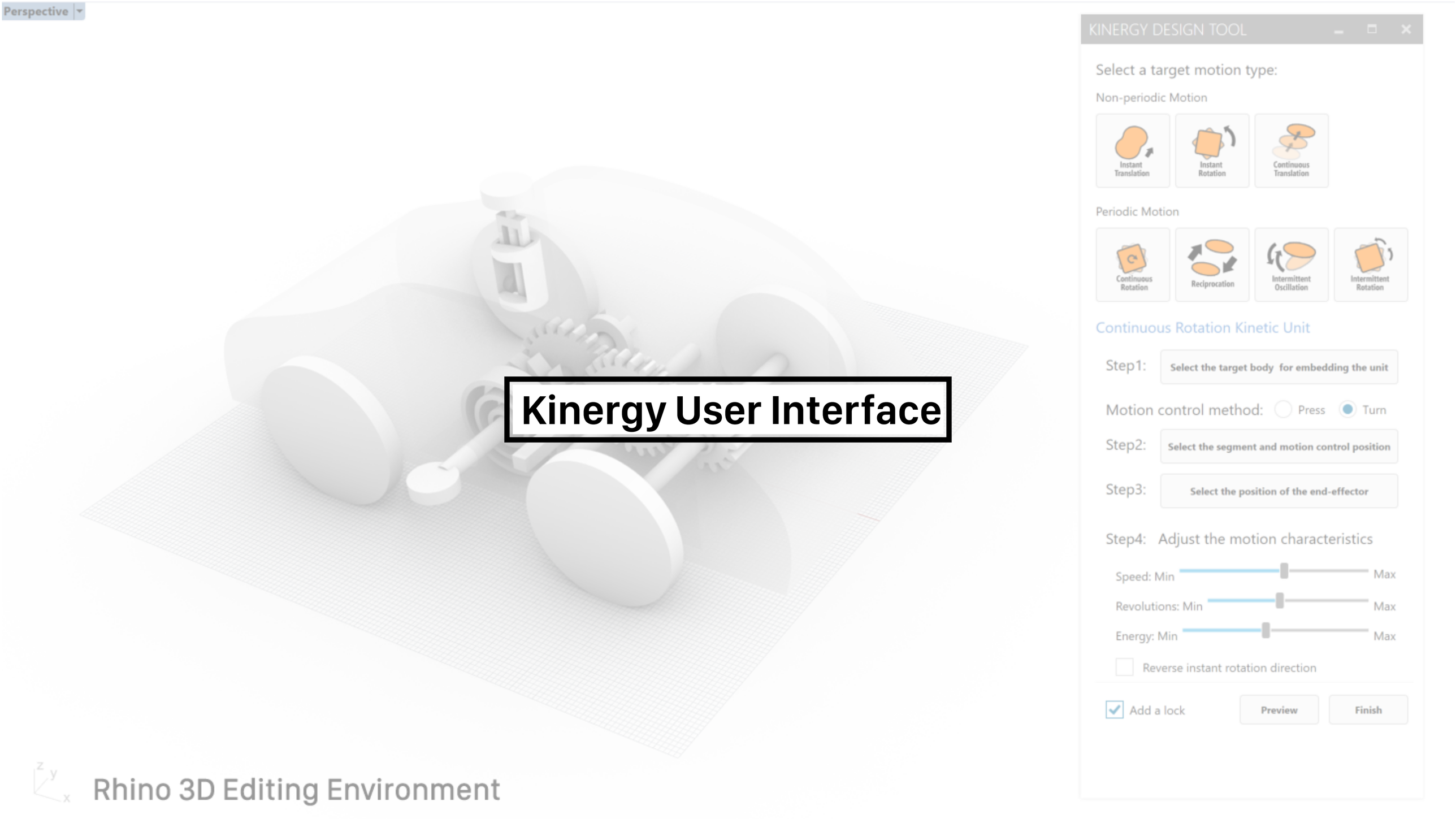
Periodic Motion Types

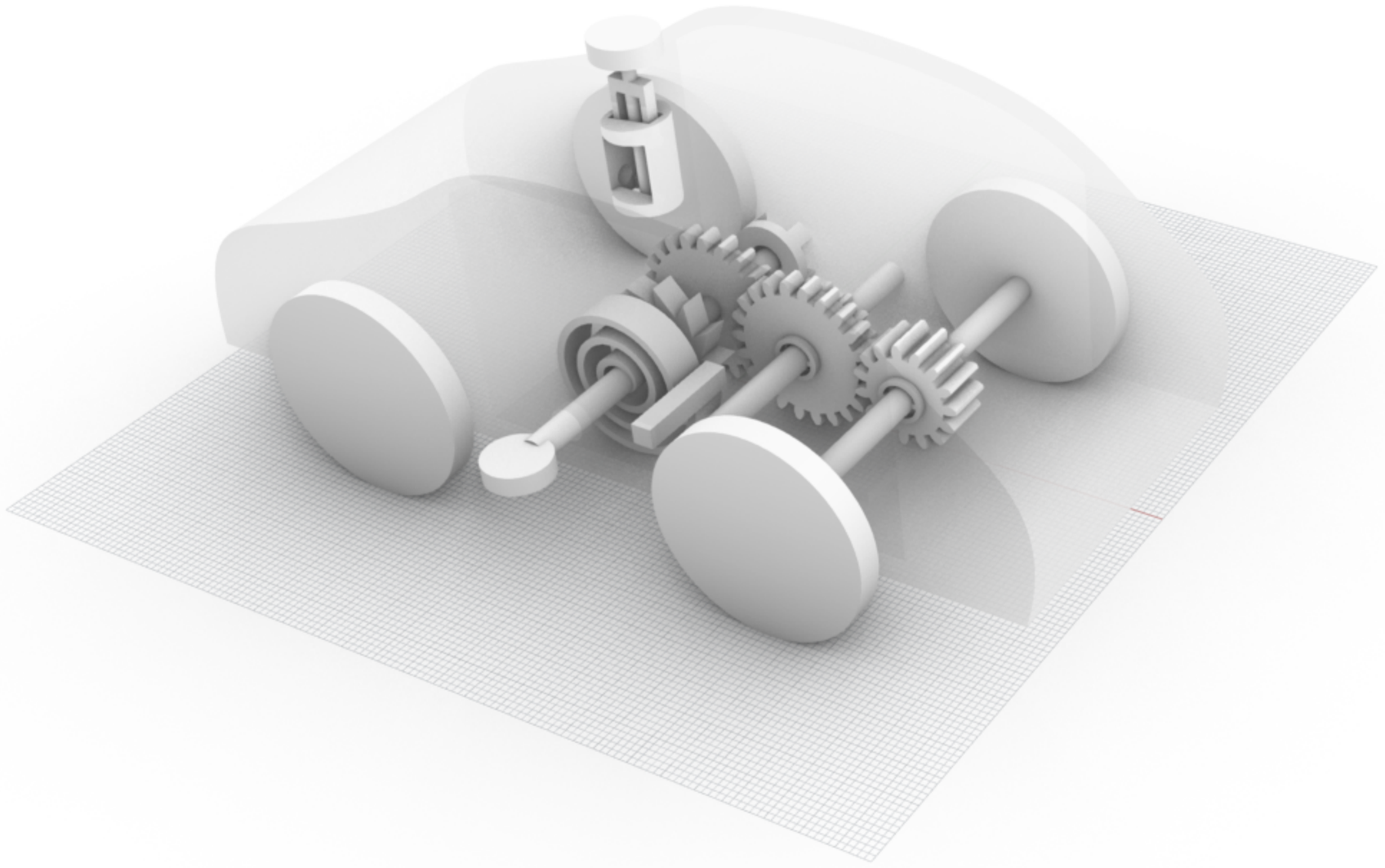
Intermittent
Rotation



Press Control

Turn Control


Perspective
KINERGY DESIGN TOOL
Select a target motion type:
Non-periodic Motion
Instant Translation
Instant Rotation
Continuous Translation
Periodic Motion
Continuous Rotation
Reciprocation
Intermittent Oscillation
Intermittent Rotation
Continuous Rotation Kinetic Unit
Step1:
Select the target body for embedding the unit
Motion control method:
Press
Turn
Step2:
Select the segment and motion control position
Step3:
Select the position of the end-effector
Step4: Adjust the motion characteristics
Speed: Min
Max
Revolutions: Min
Max
Energy: Min
Max
Reverse instant rotation direction
Add a lock
Preview
Finish
Kinergy User Interface
Rhino 3D Editing Environment

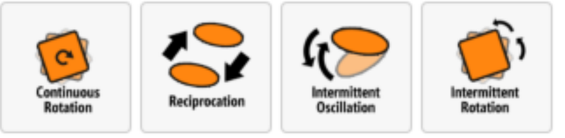


KINERGY DESIGN TOOL

Select a target motion type:

Non-periodic Motion

Periodic Motion



Continuous Rotation Kinetic Unit

Step1: Select the target body for embedding the unit

Motion control method: Press Turn

Step2: Select the segment and motion control position

Step3: Select the position of the end-effector

Step4: Adjust the motion characteristics

Speed: Min — Max

Revolutions: Min — Max

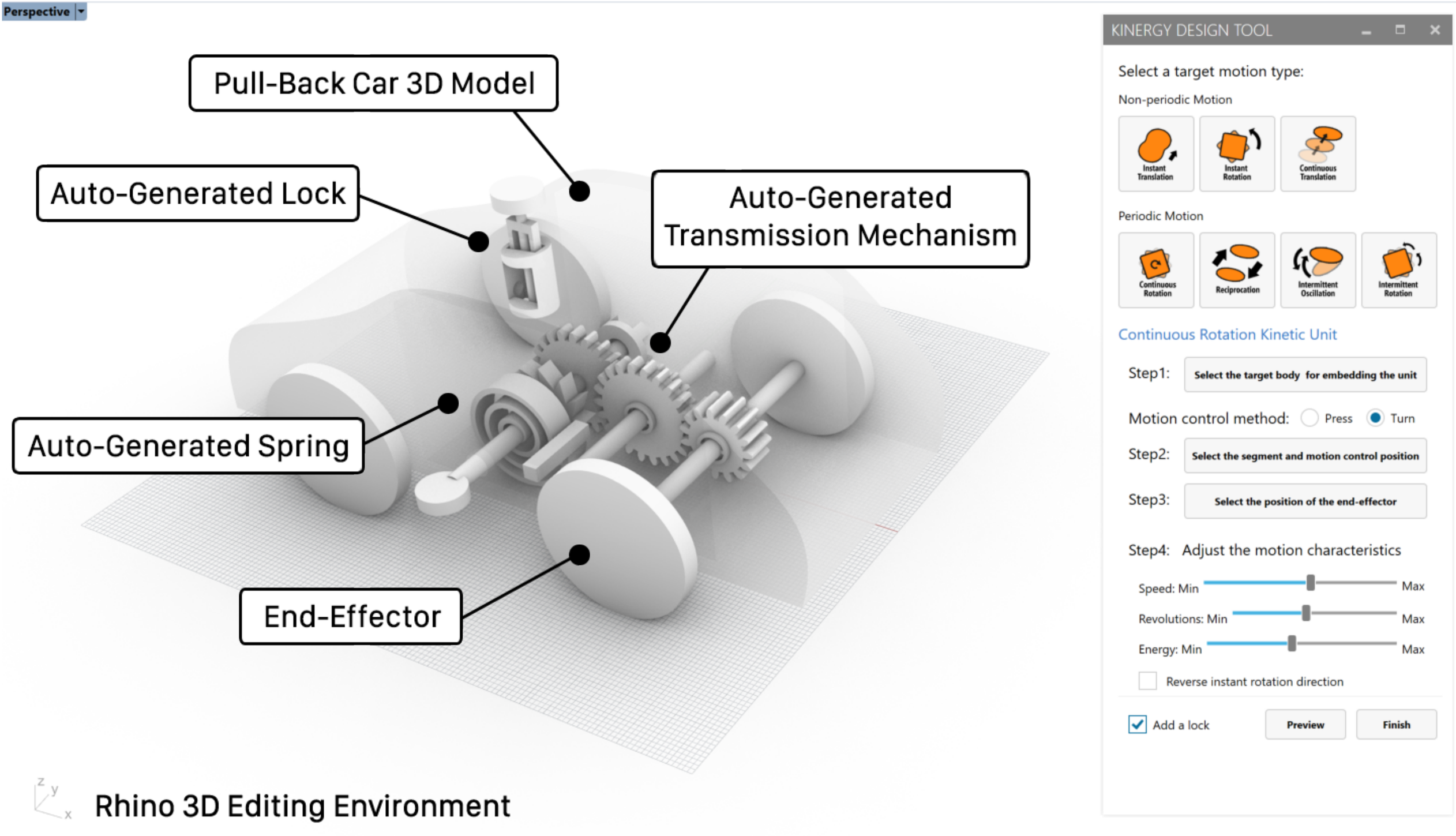
Energy: Min — Max

Reverse instant rotation direction

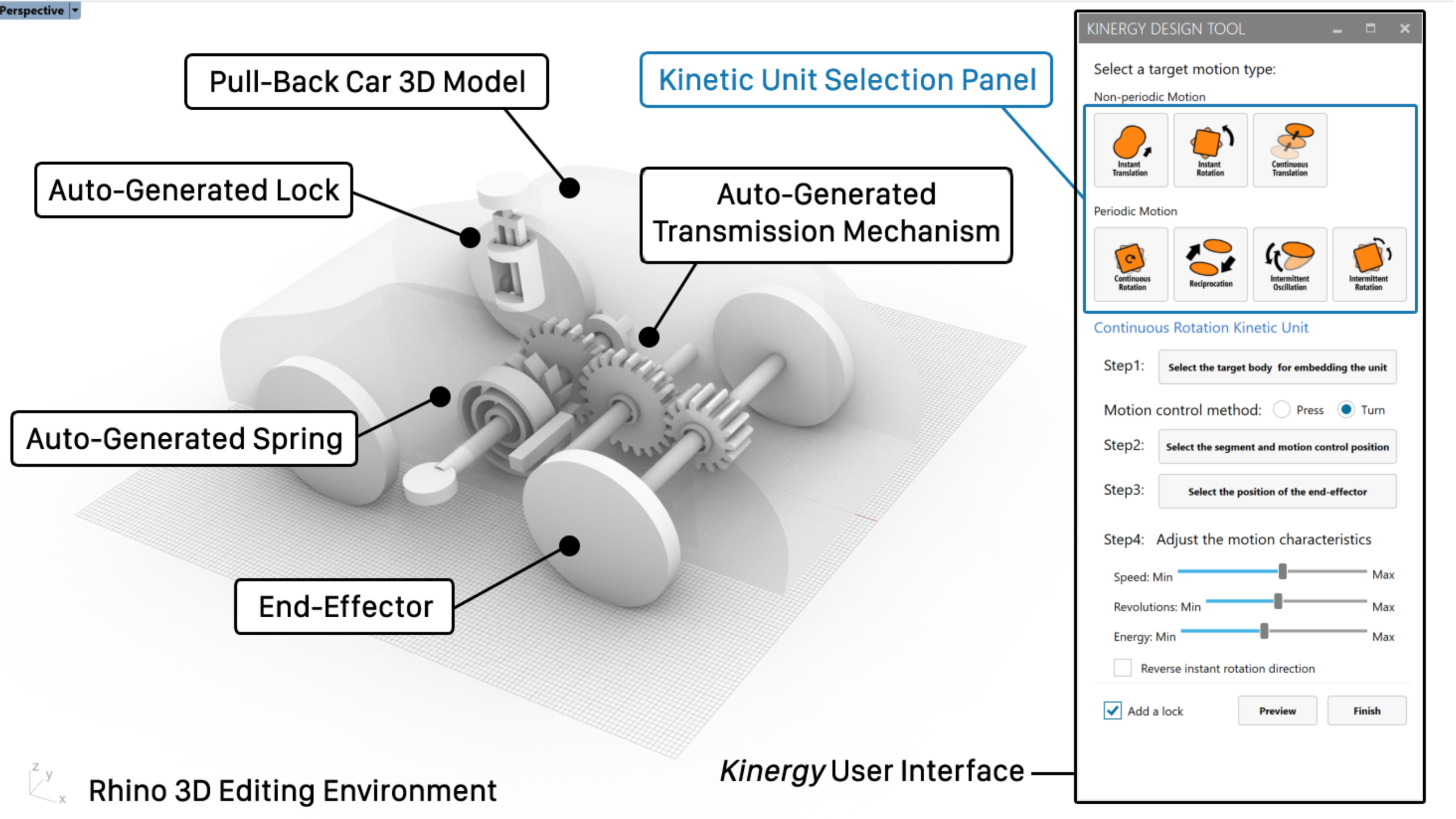
Add a lock | Preview | Finish

z y x

Rhino 3D Editing Environment



Rhino 3D Editing Environment


Perspective
Pull-Back Car 3D Model
Kinetic Unit Selection Panel
Auto-Generated Lock
Auto-Generated Transmission Mechanism
Auto-Generated Spring
End-Effector
KINERGY DESIGN TOOL
Select a target motion type:
Non-periodic Motion
Instant Translation
Instant Rotation
Continuous Translation
Periodic Motion
Continuous Rotation
Reciprocation
Intermittent Oscillation
Intermittent Rotation
Continuous Rotation Kinetic Unit
Step1:
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Turn
Step2:
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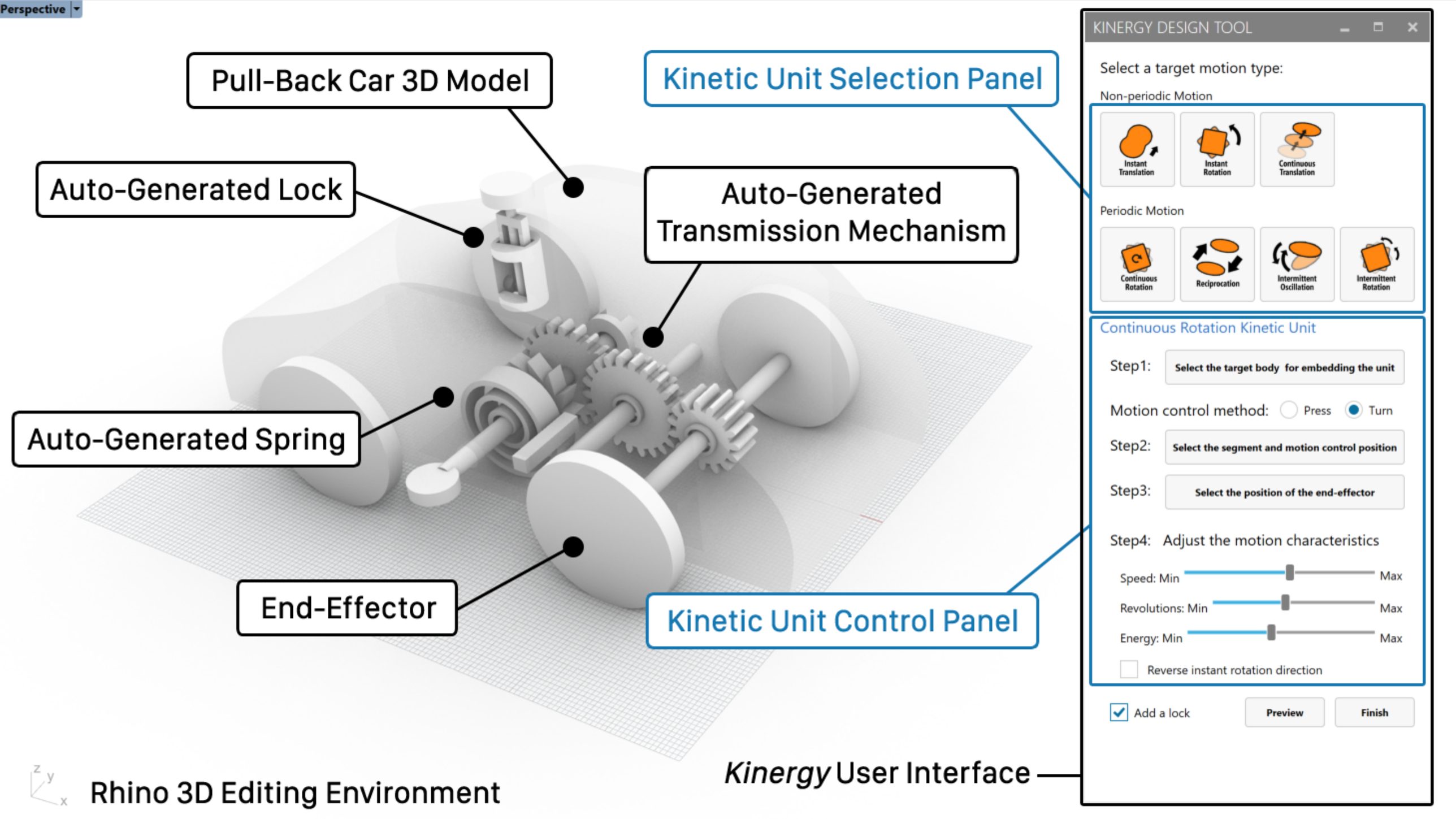
Step3:
Select the position of the end-effector
Step4: Adjust the motion characteristics
Speed: Min
Max
Revolutions: Min
Max
Energy: Min
Max
Reverse instant rotation direction
Add a lock
Preview
Finish
Rhino 3D Editing Environment
Kinergy User Interface


Perspective
Pull-Back Car 3D Model
Auto-Generated Lock
Auto-Generated Transmission Mechanism
Auto-Generated Spring
End-Effector
Kinetic Unit Selection Panel
Kinetic Unit Control Panel
KINERGY DESIGN TOOL
Select a target motion type:
Non-periodic Motion
Instant Translation
Instant Rotation
Continuous Translation
Periodic Motion
Continuous Rotation
Reciprocation
Intermittent Oscillation
Intermittent Rotation
Continuous Rotation Kinetic Unit
Step1:
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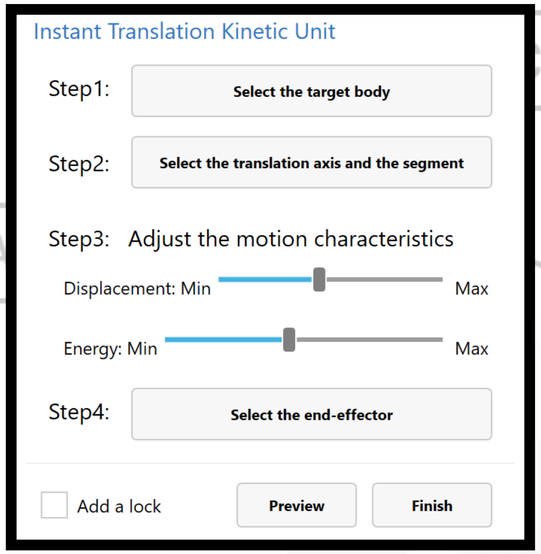
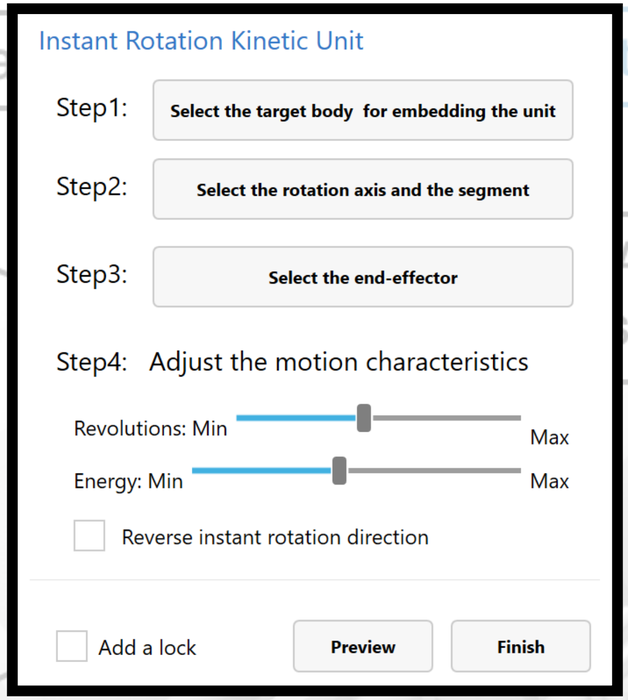
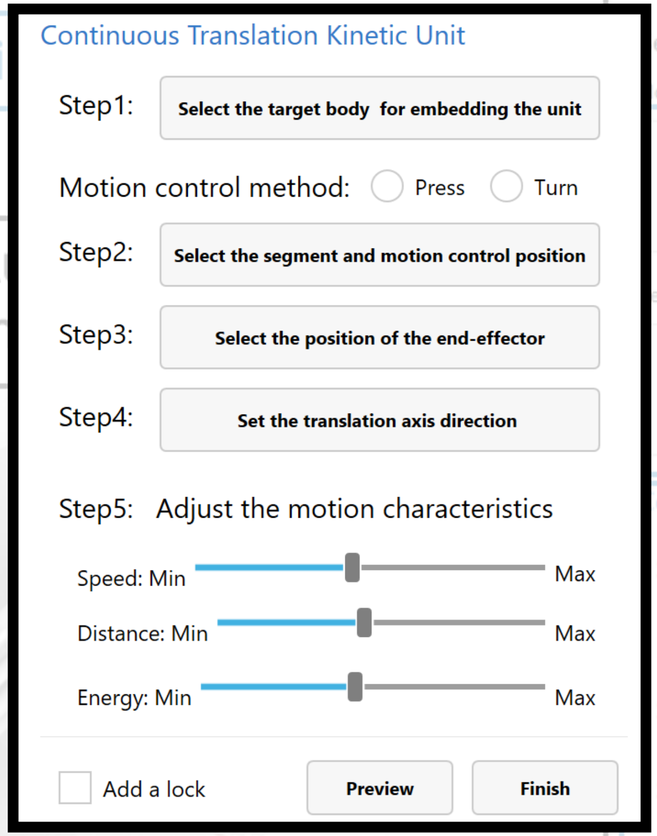
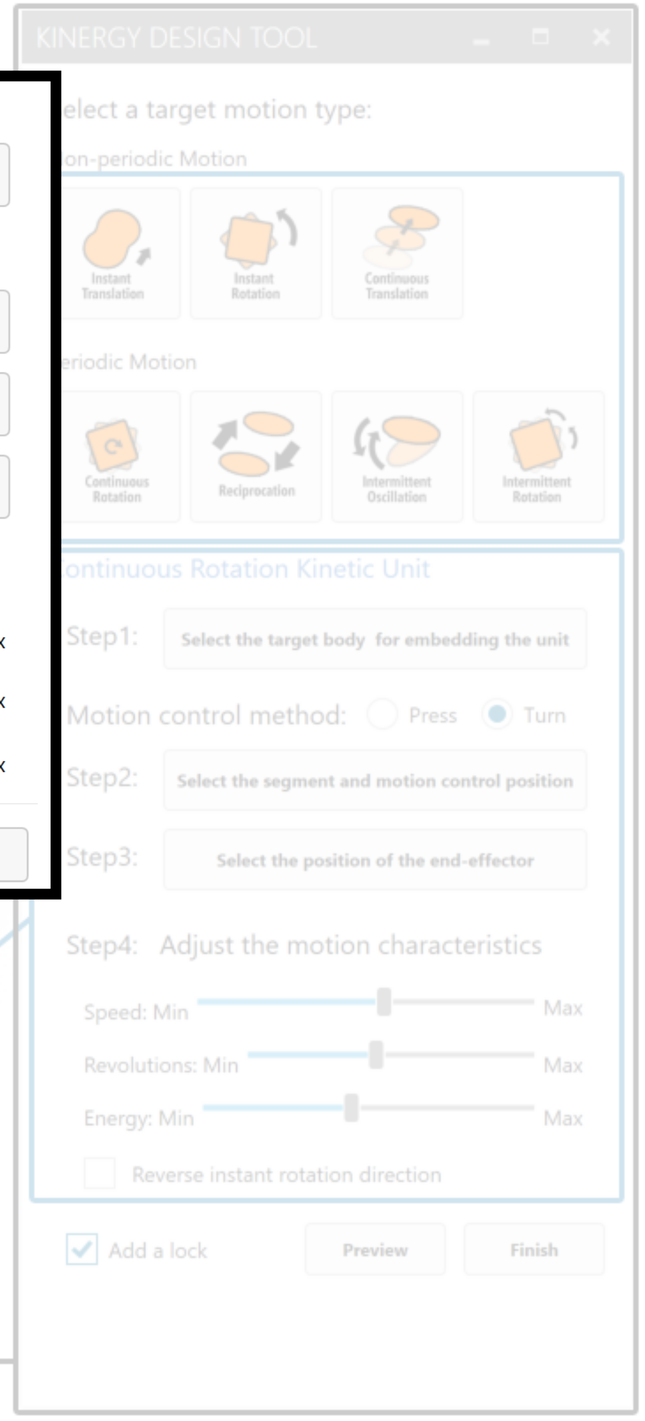
Speed: Min
Max
Revolutions: Min
Max
Energy: Min
Max
Reverse instant rotation direction
Add a lock
Preview
Finish
Rhino 3D Editing Environment
Kinergy User Interface









Auto-Generated Spring

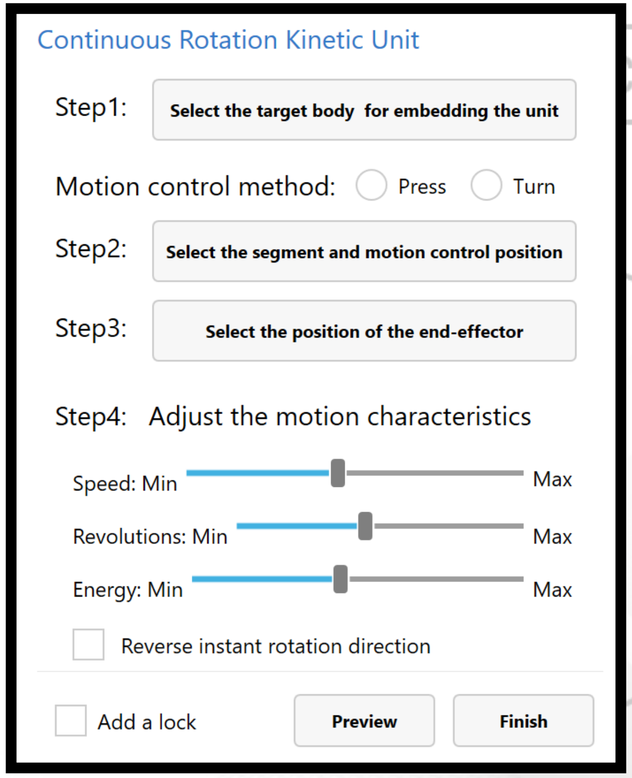
End-Effector

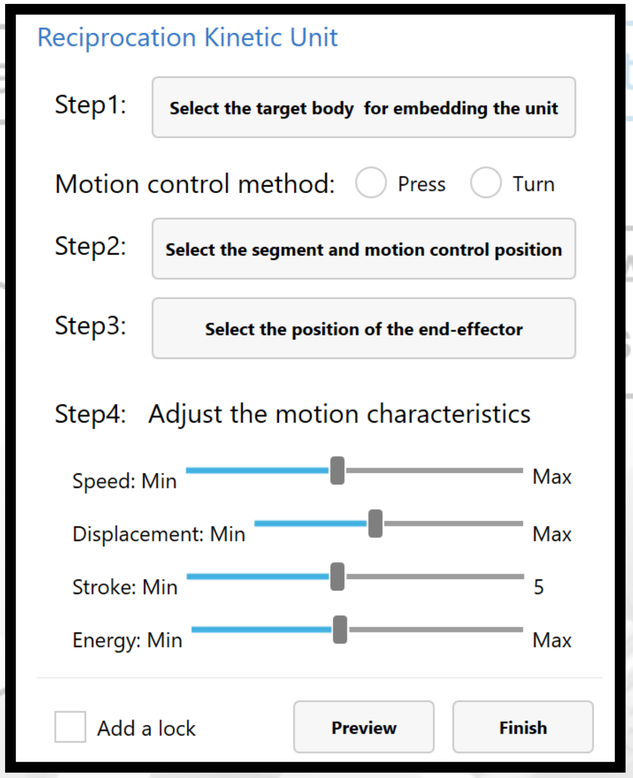
Kinetic Unit Control Panel

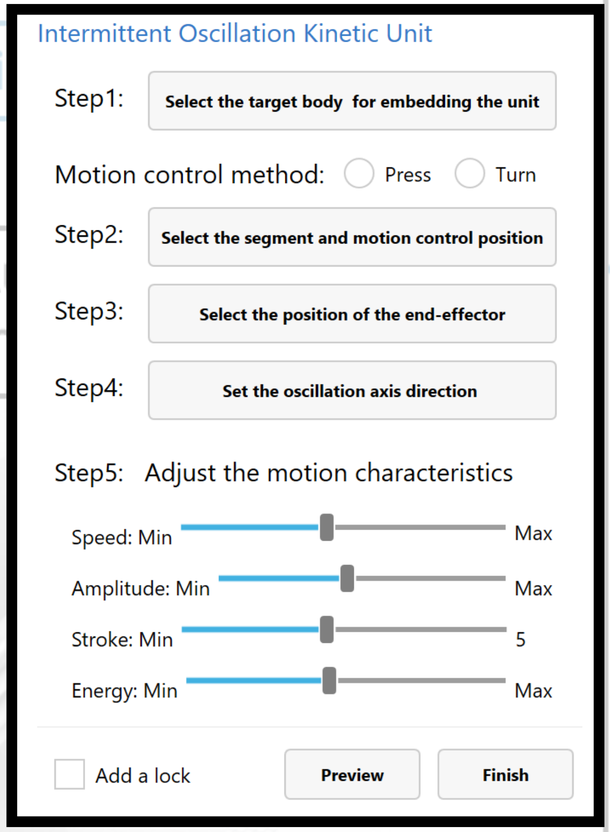
Non-Periodic Motion Control Panel

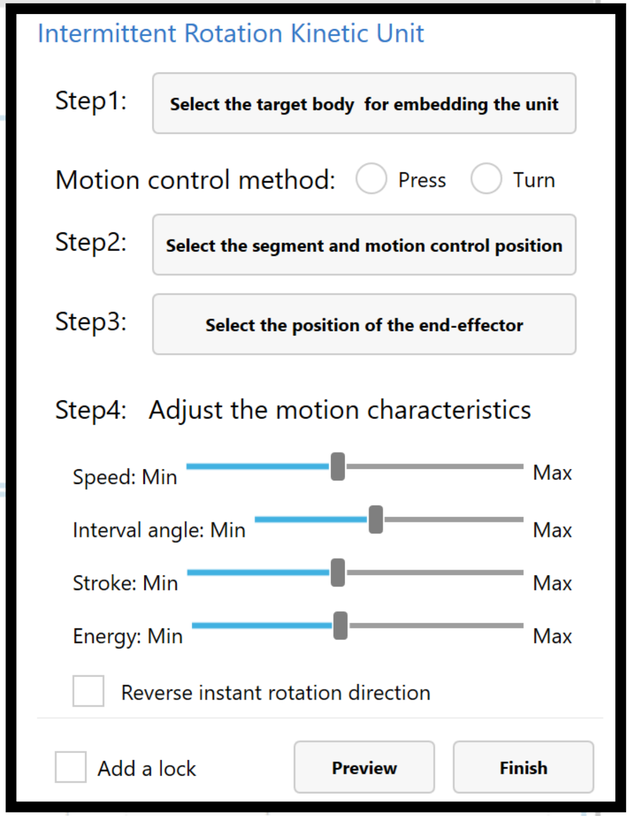
Kinergy User Interface

Rhino 3D Editing Environment









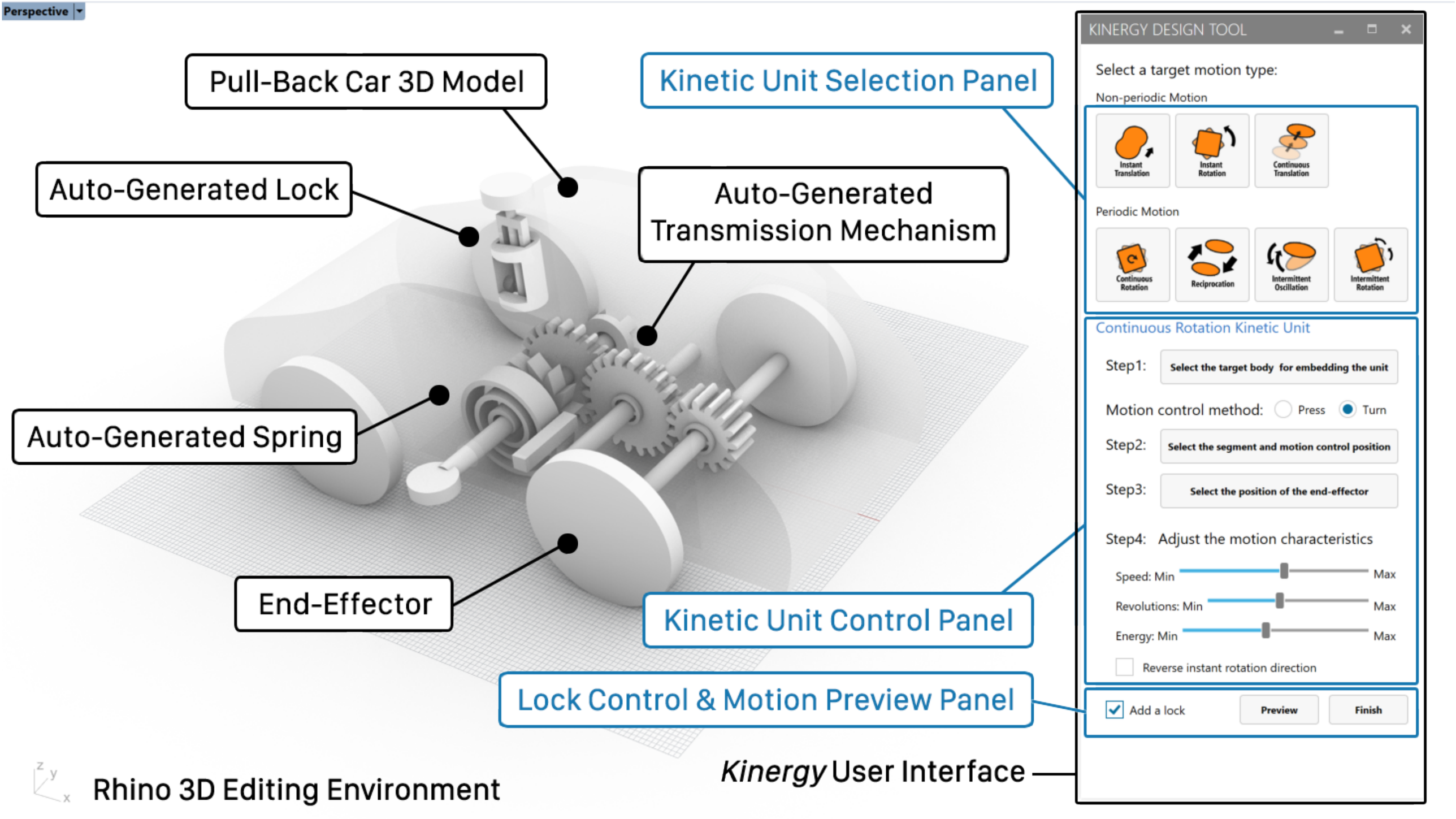
End-Effector

Kinetic Unit Control Panel

Kinergy User Interface

Rhino 3D Editing Environment

Periodic Motion Control Panel


Perspective
Pull-Back Car 3D Model
Auto-Generated Lock
Auto-Generated Transmission Mechanism
Auto-Generated Spring
End-Effector
Kinetic Unit Selection Panel
Kinetic Unit Control Panel
Lock Control & Motion Preview Panel
KINERGY DESIGN TOOL
Select a target motion type:
Non-periodic Motion
Instant Translation
Instant Rotation
Continuous Translation
Periodic Motion
Continuous Rotation
Reciprocation
Intermittent Oscillation
Intermittent Rotation
Continuous Rotation Kinetic Unit
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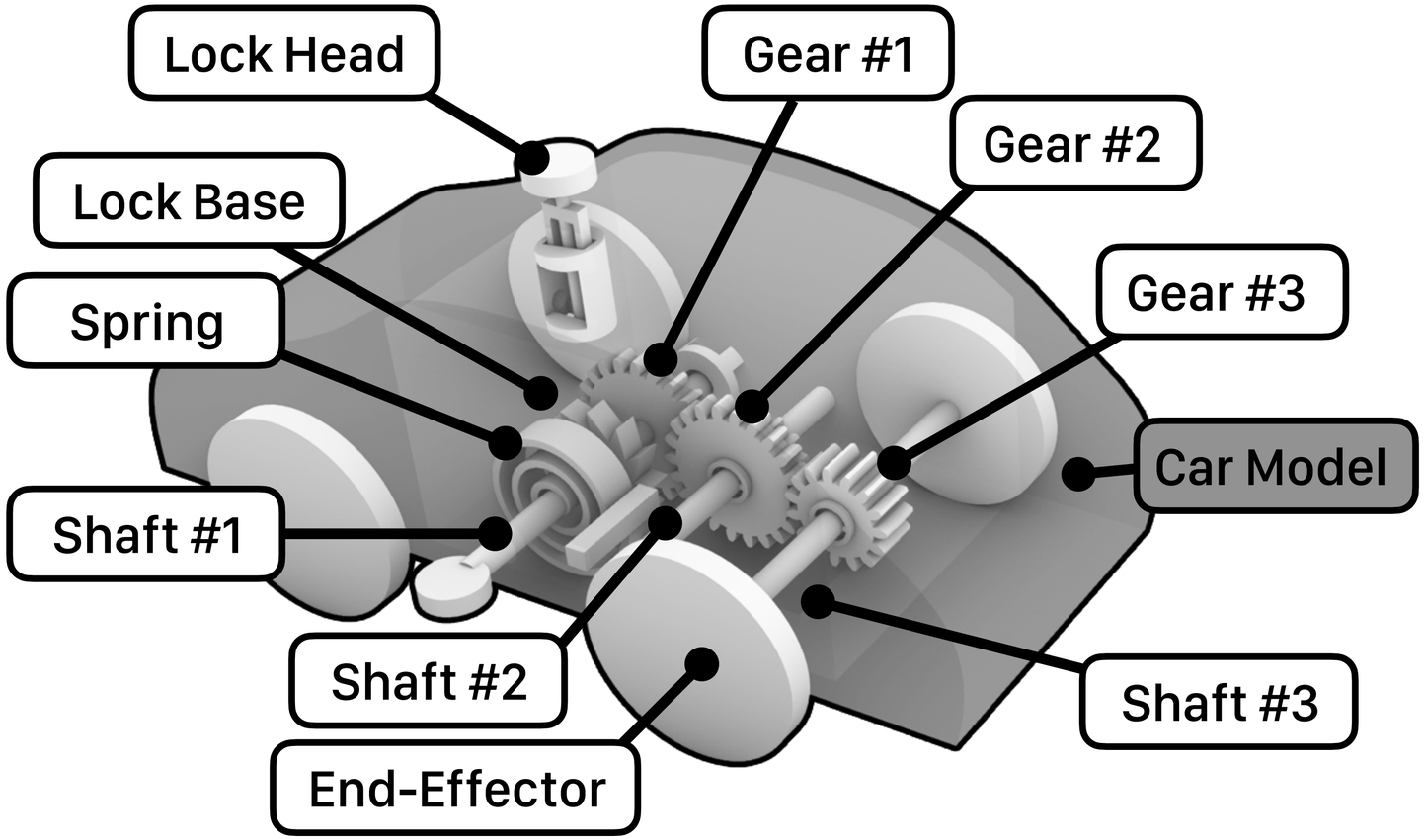
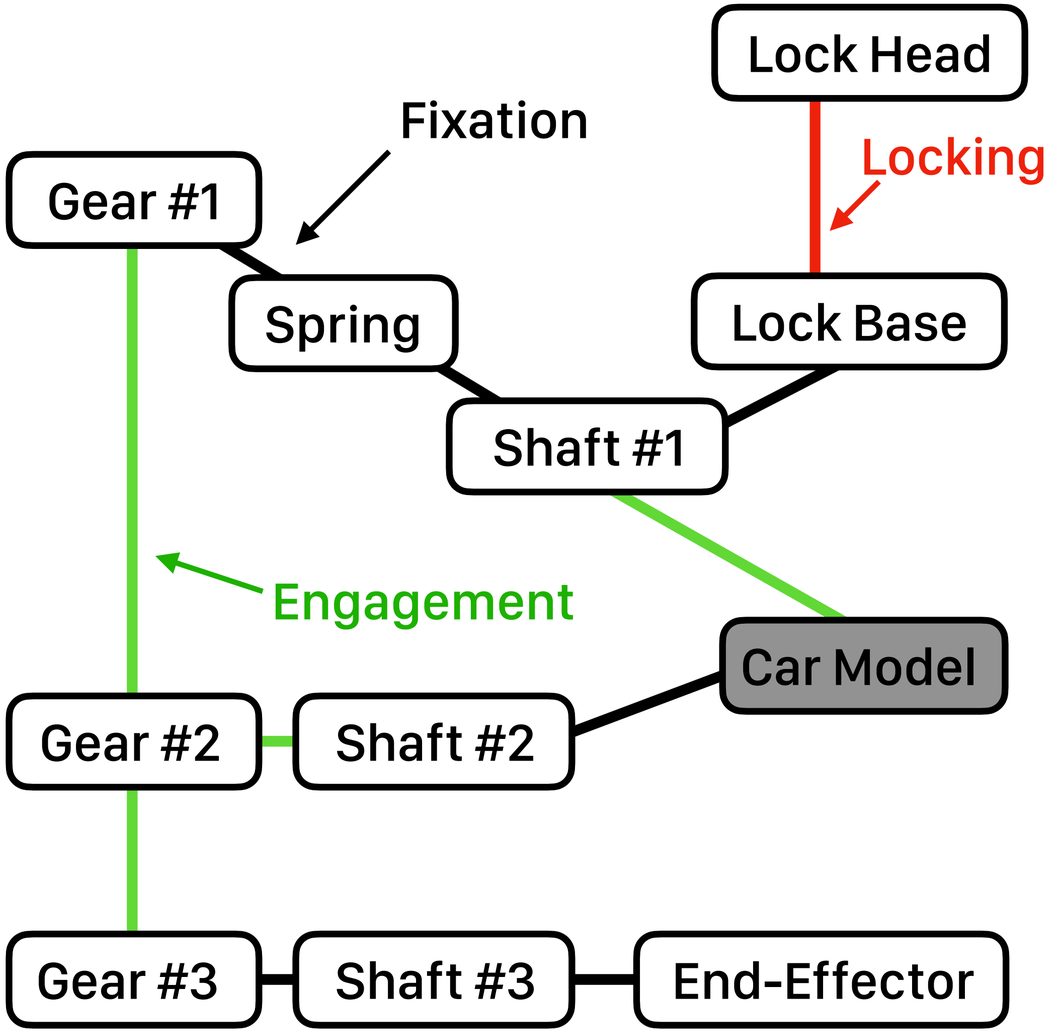
Max
Revolutions: Min
Max
Energy: Min
Max
Reverse instant rotation direction
Add a lock
Preview
Finish
Rhino 3D Editing Environment
Kinergy User Interface

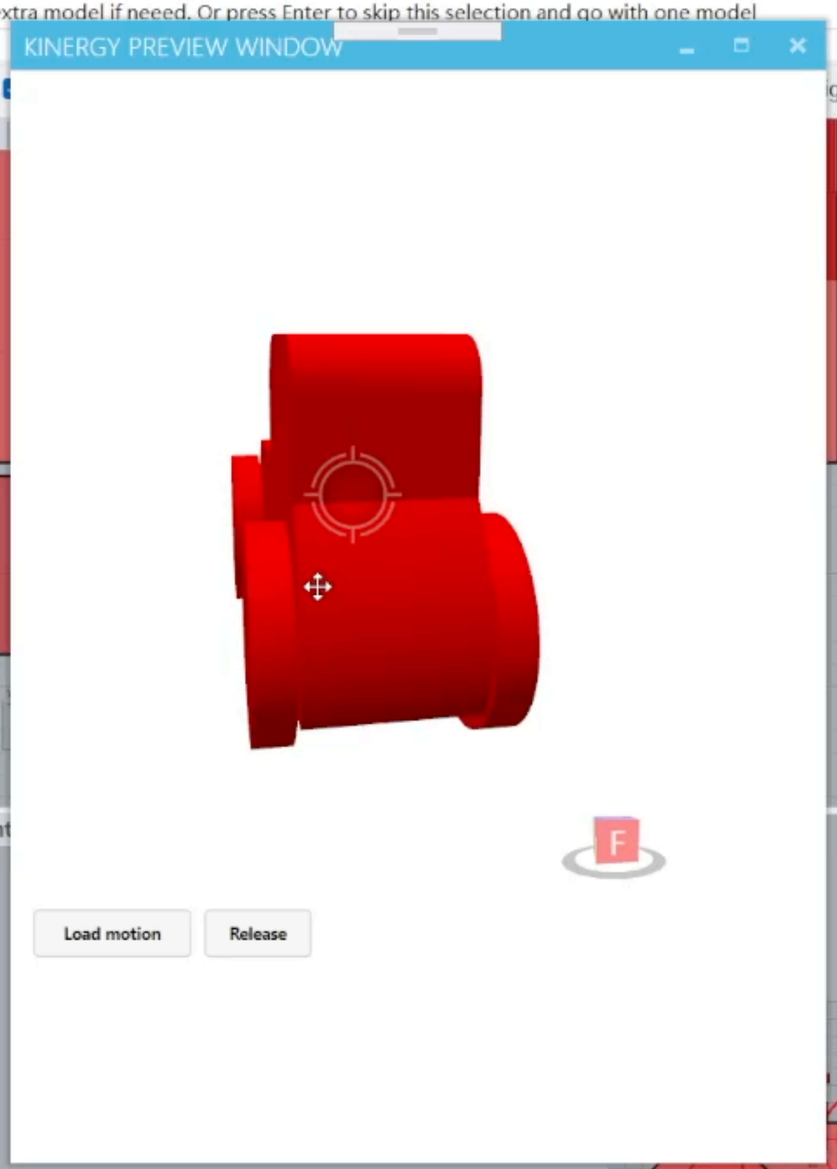
Motion Preview





Kinetic Unit Enabled Pullback Car Example

extra model if needed. Or press Enter to skip this selection and go with one model



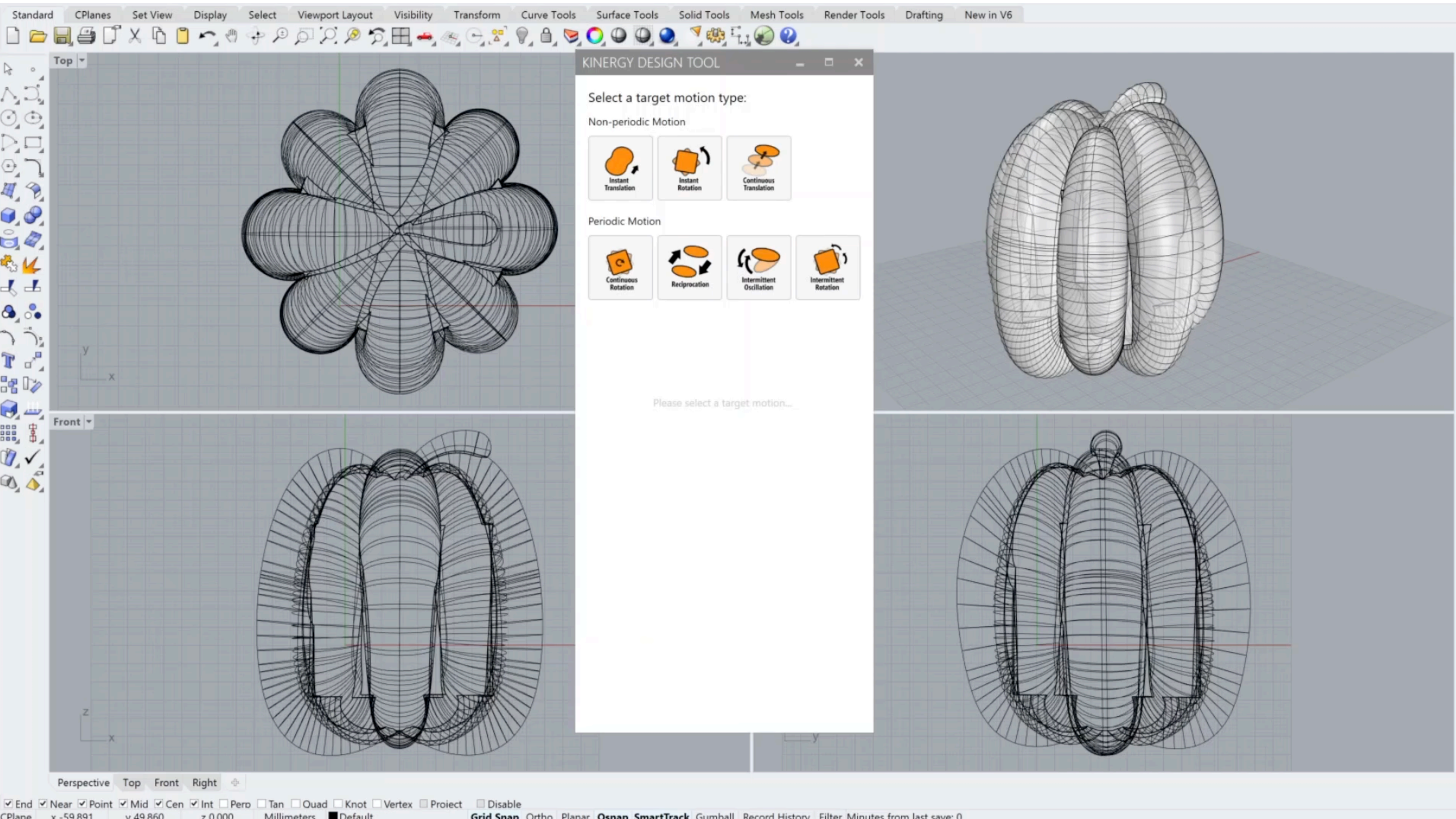
ghts Blocks Control Points Point Clouds Hatches Others Disable Sub-objects

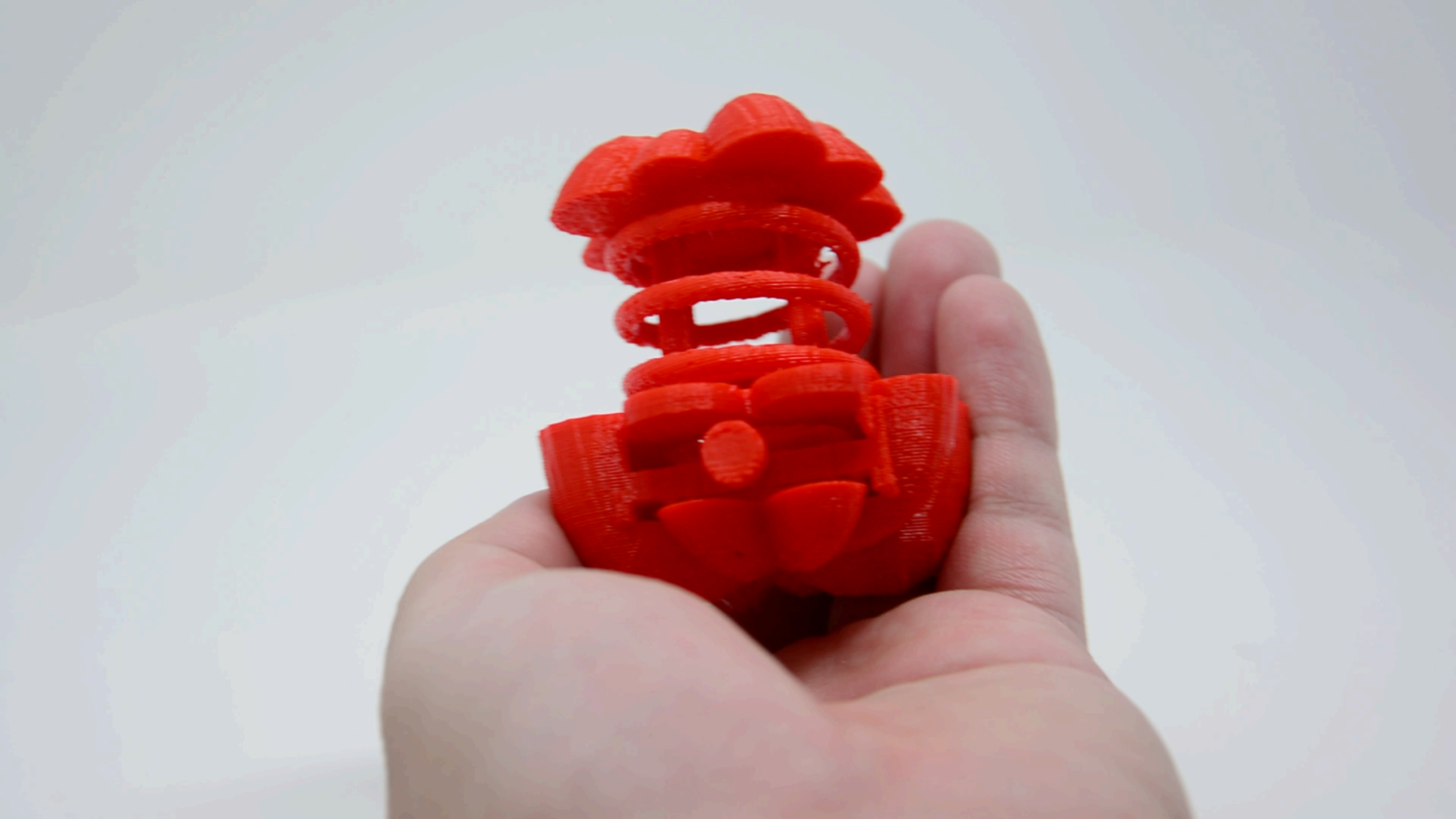
Perspective

Right

Walkthrough:

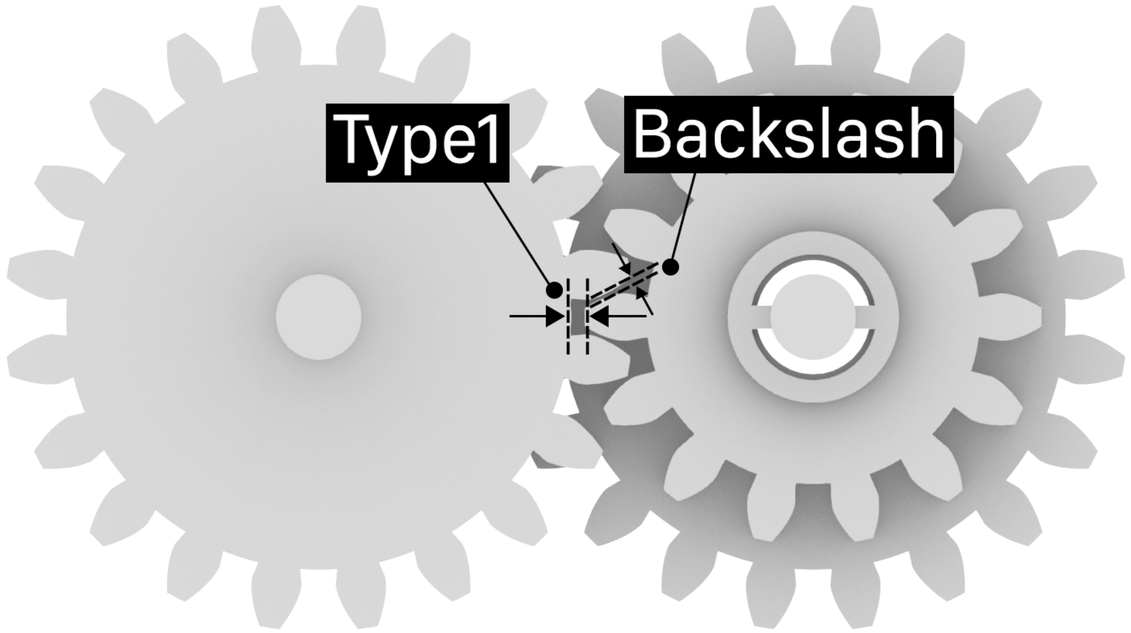
making a self-popped Mr. Halloween Pumpkin using an instant translation kinetic unit

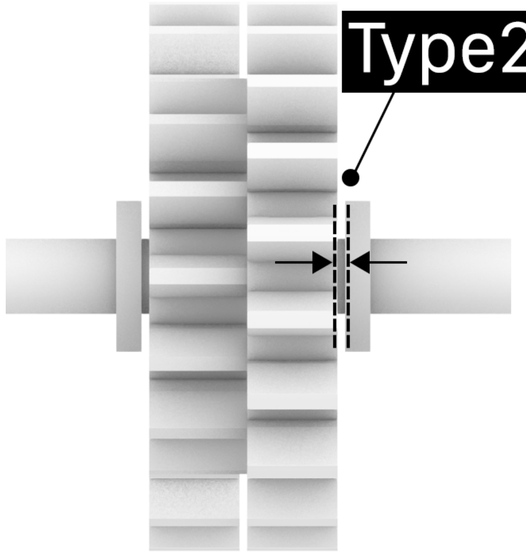

Standard
CPlanes
Set View
Display
Select
Viewport Layout
Visibility
Transform
Curve Tools
Surface Tools
Solid Tools
Mesh Tools
Render Tools
Drafting
New in V6
Top
Front
Perspective
Top
Front
Right
KINERGY DESIGN TOOL
Select a target motion type:
Non-periodic Motion
Instant Translation
Instant Rotation
Continuous Translation
Periodic Motion
Continuous Rotation
Reciprocation
Intermittent Oscillation
Intermittent Rotation
Please select a target motion...
End
Near
Point
Mid
Cen
Int
Perp
Tan
Quad
Knot
Vertex
Project
Disable
Millimeters
Default
Grid Snap
Ortho
Planar
Osnap
SmartTrack
Gumball
Record History
Filter
Minutes from last save: 0

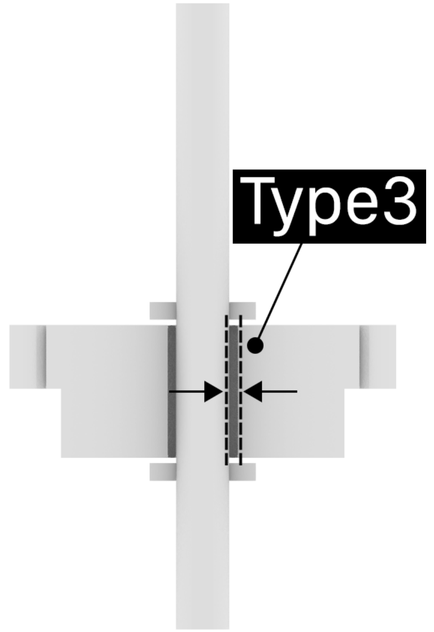


Fabrication

Tolerance Types







Slicer: Ultimaker Cura
3D Printer: Ultimaker 3 & 3 Extended
Printing Material: PLA
Supporting Material: PVA (water dissolvable)

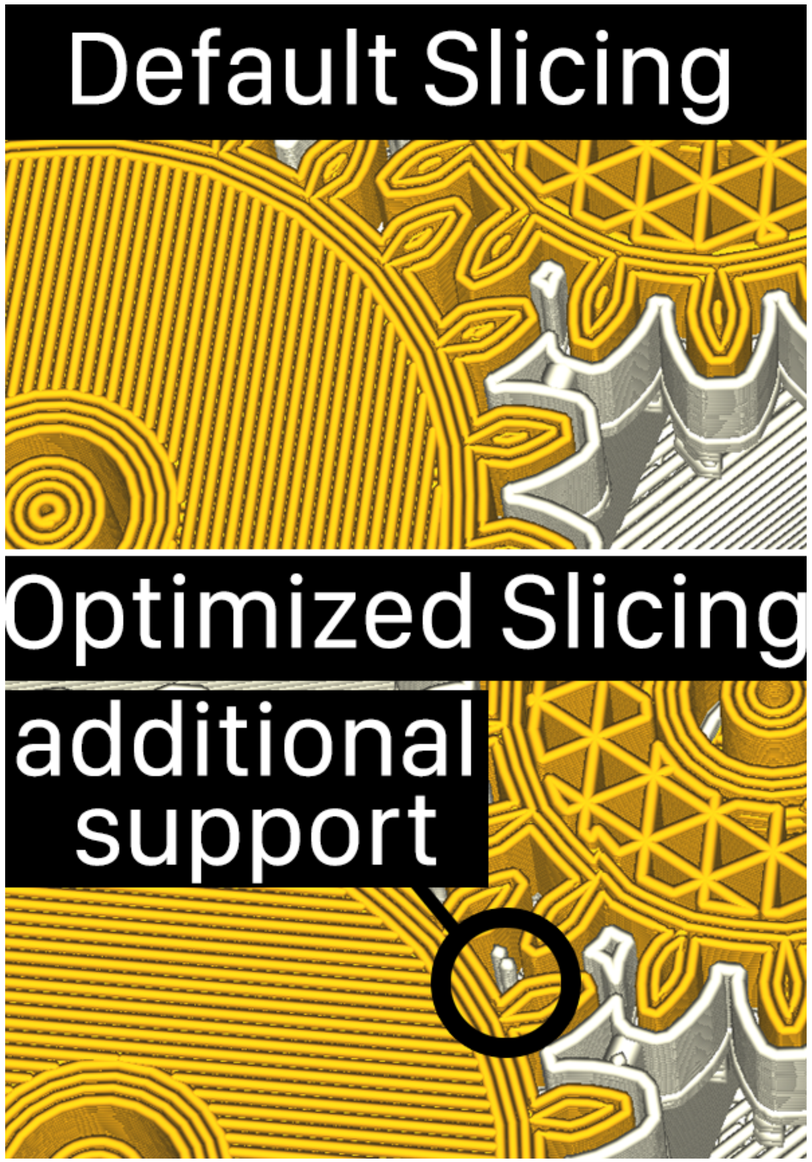
With a printer that uses a 0.4mm-sized printing nozzle and 0.15mm printing layer height

Type 1: 0.3mm
Type 2: 0.25mm
Type 3: 0.35mm

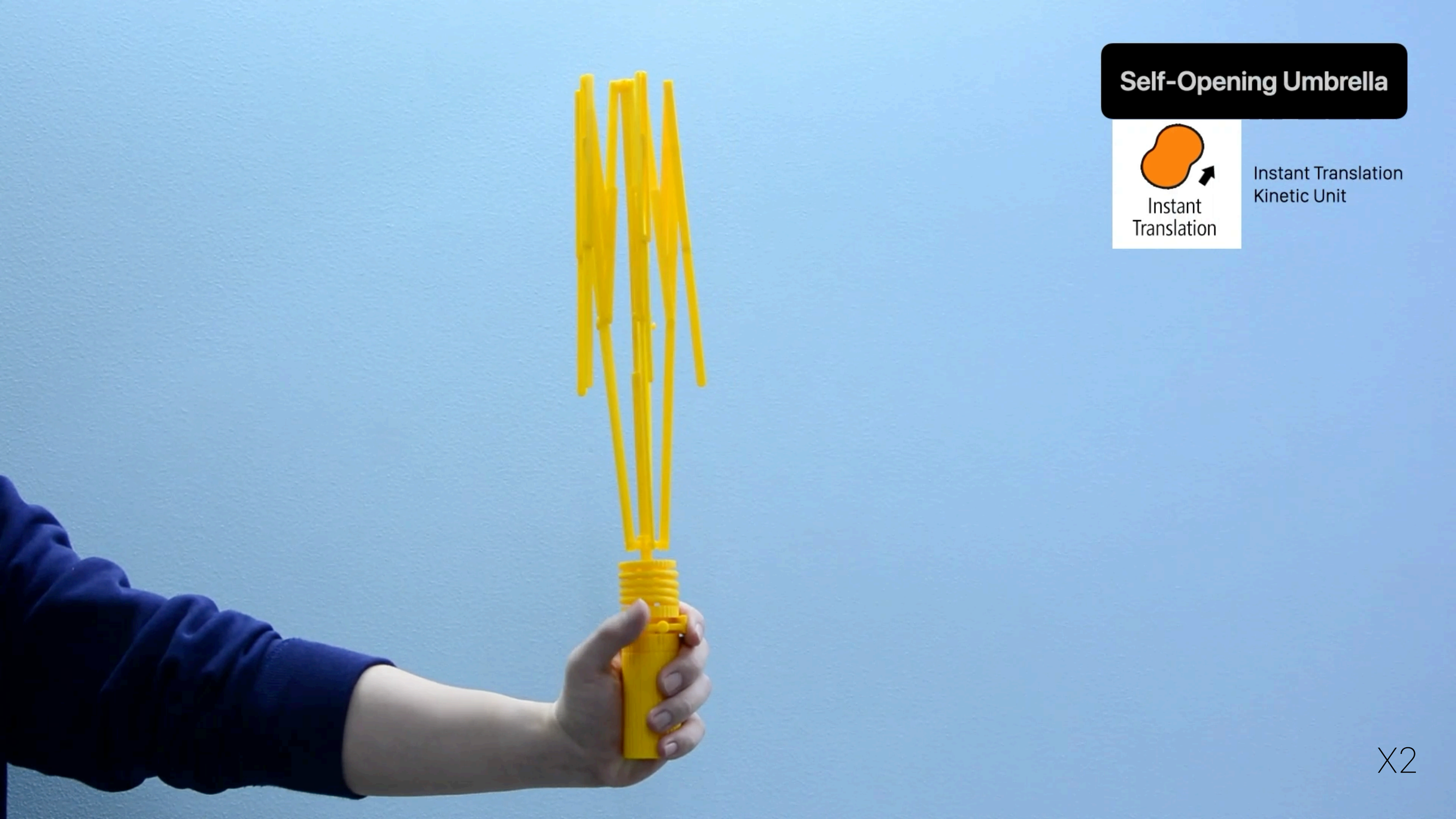
Slicing and Printing Settings

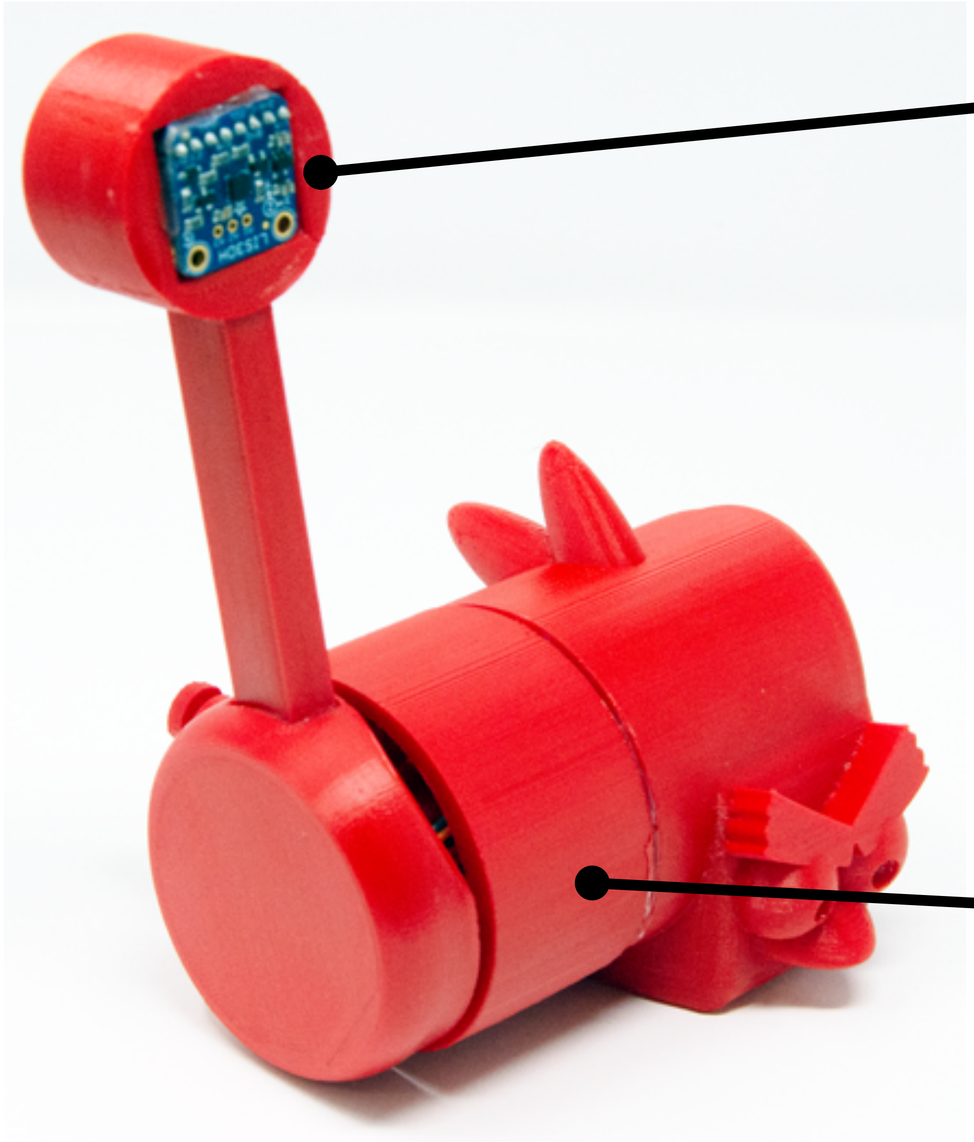
Printing orientation

Exclusive slicing tolerance
A minimal negative **0.04mm**
horizontal expansion

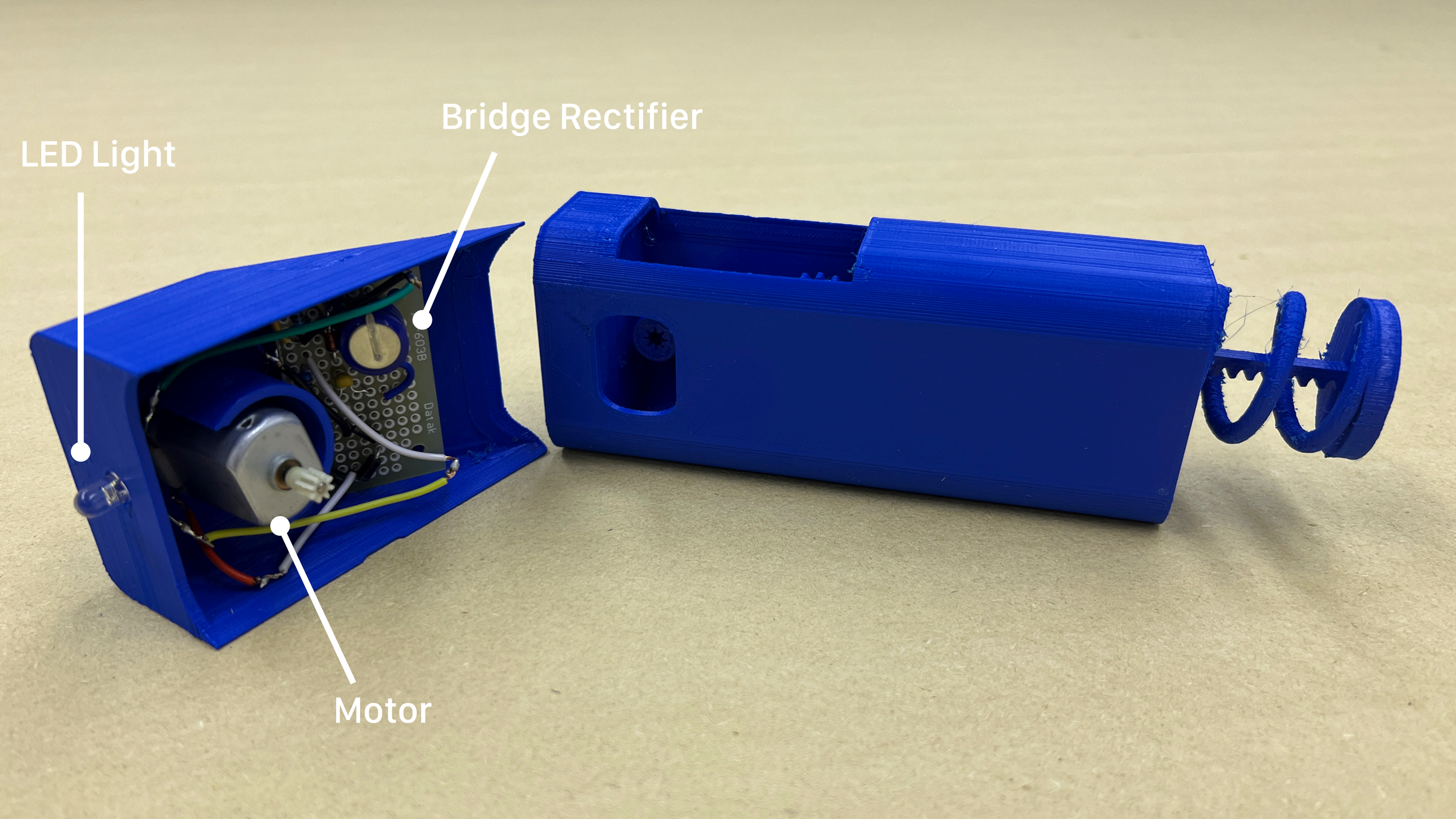


Kinergy Applications

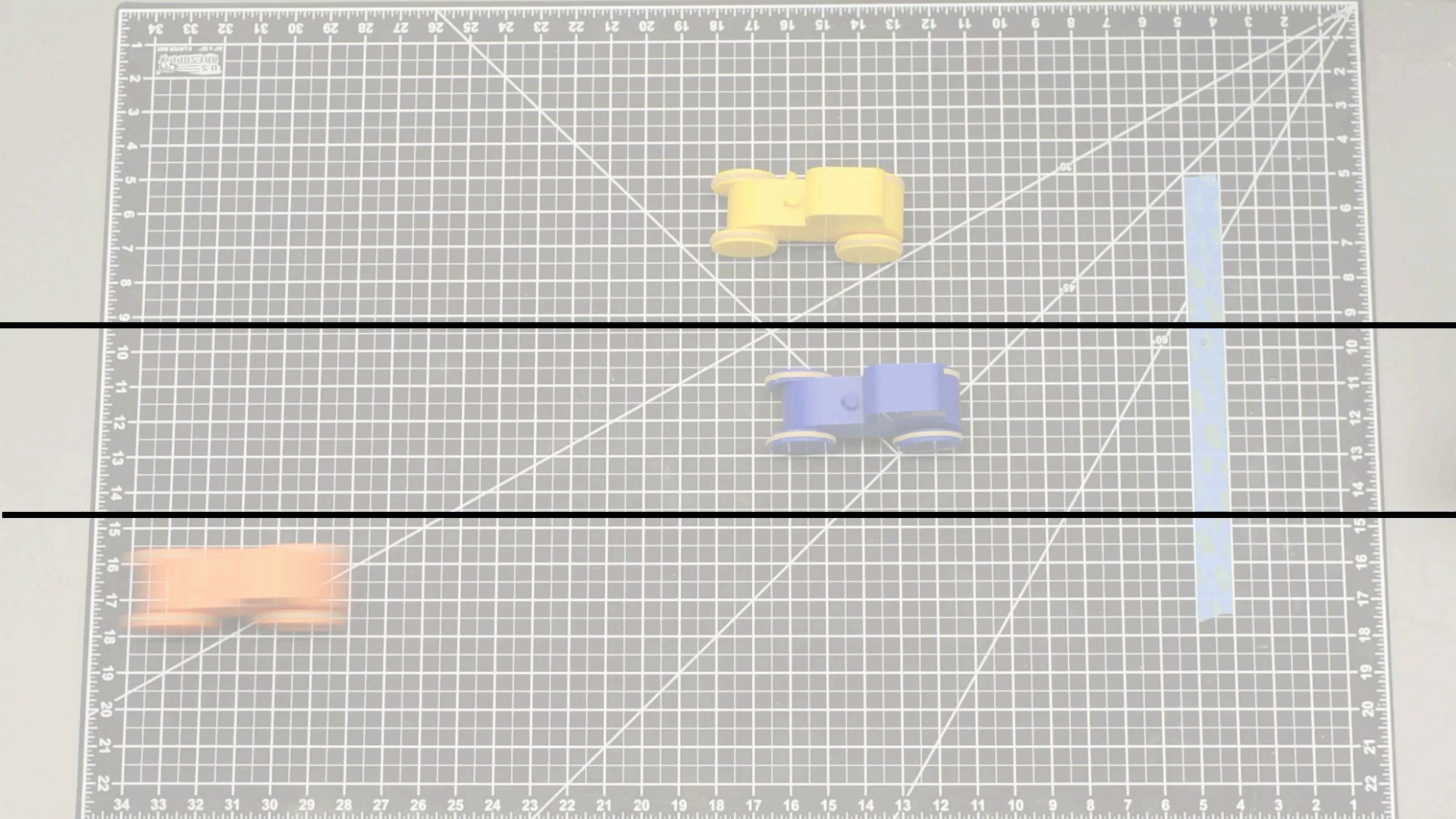

Self-Opening Umbrella
Instant Translation
Instant Translation
Kinetic Unit
X2


Accelerometer
Circuit (hidden)


X2


LED Light
Bridge Rectifier
Motor


X1.5




Trash Can
Continuous Translation
Continuous Translation
Kinetic Unit
(Press Control)
WORKS 3 WAYS
WORKS GREAT ON PLASTIC
#1 BRAND
PHOSPHATE FREE

Future Work

Geometry Complexity: size limitations, object topology

Printability and Robustness: anisotropy of 3D printing, resolution, materials, printing methods, friction

Energy-Releasing Triggers: custom triggers, concatenating multiple kinetic units

Design Tool Improvements: instructional guidances, compatible with other 3D printing methods, realistic simulation, design workshop

THANK YOU

Code:

https://github.com/makeabilitylab/Kinergy

Kinergy

Creating 3D Printable Motion using Embedded Kinetic Energy


Liang He


Xia Su

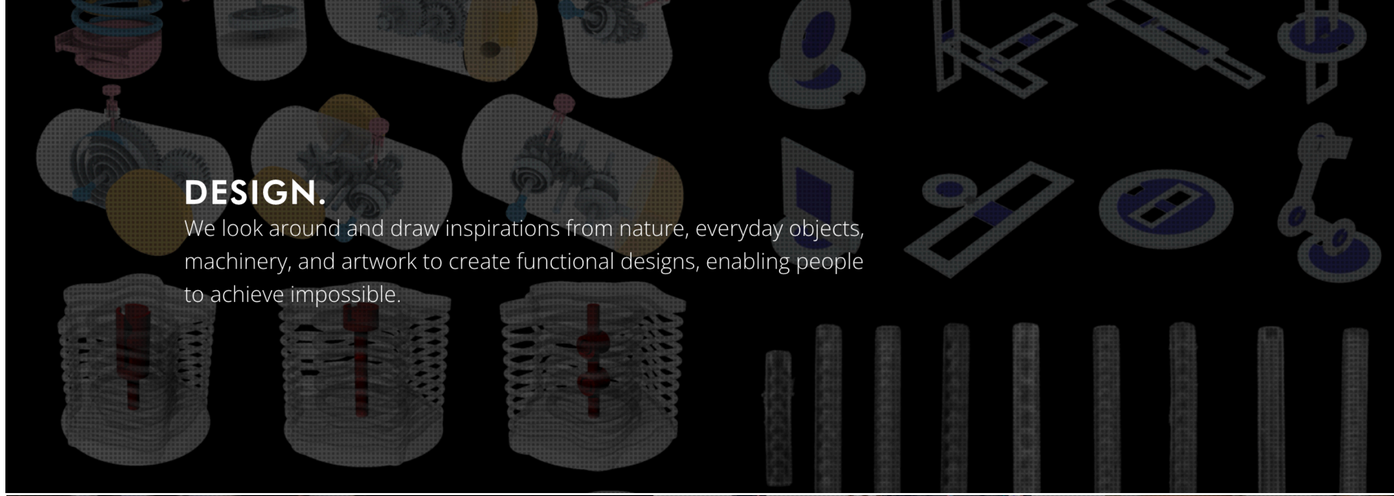

Huaishu Peng


Jeff Lipton


Jon Froehlich

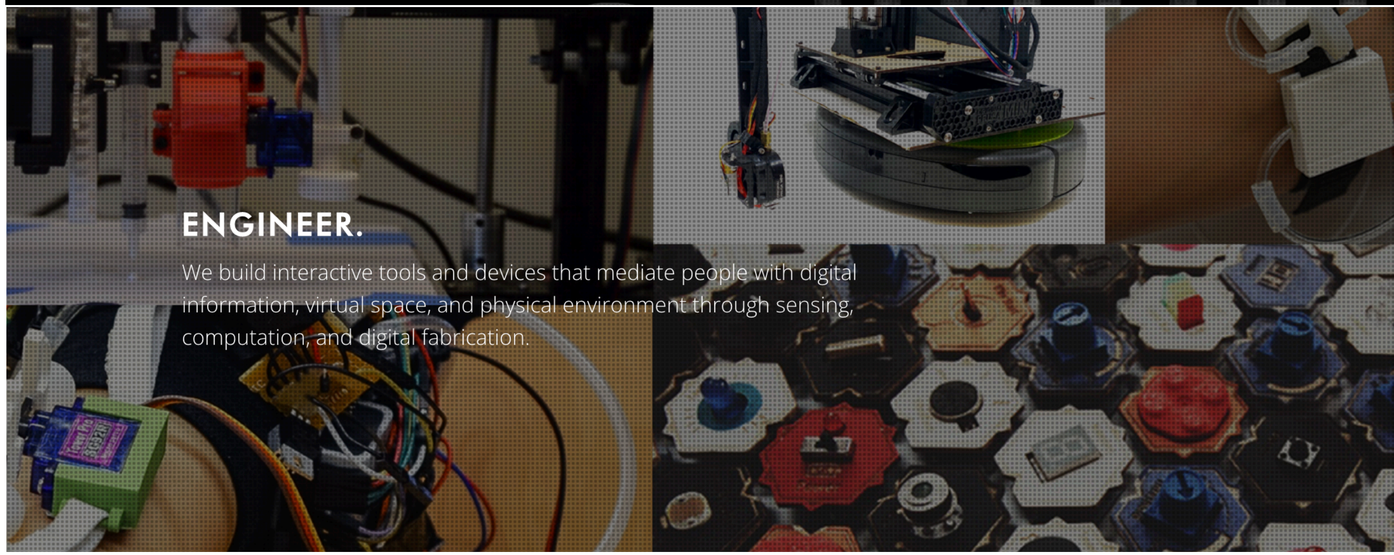
DE4M LAB

Polytechnic Institute
Purdue University
www.de4m.xyz



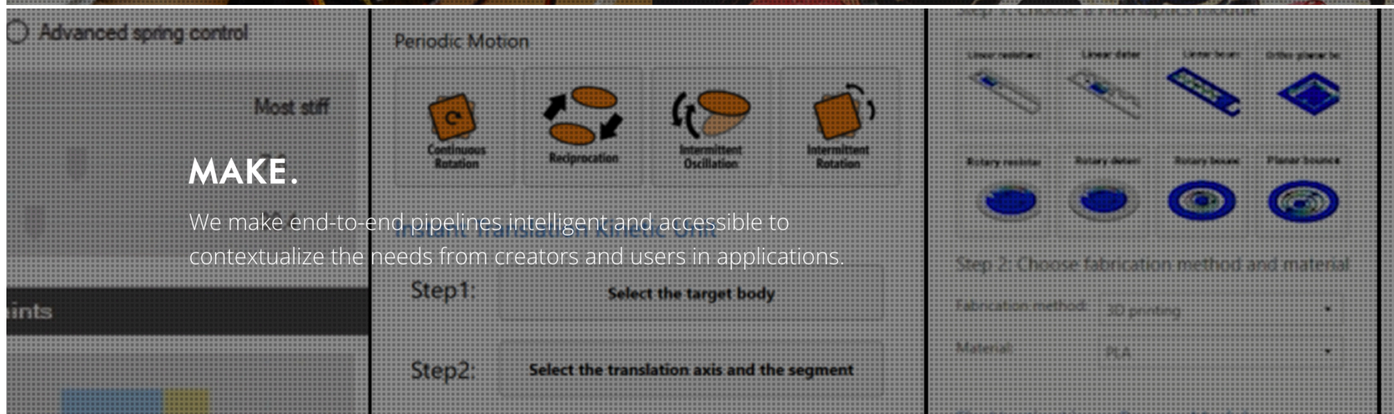
DESIGN.

We look around and draw inspirations from nature, everyday objects, machinery, and artwork to create functional designs, enabling people to achieve impossible.



ENGINEER.

We build interactive tools and devices that mediate people with digital information, virtual space, and physical environment through sensing, computation, and digital fabrication.



MAKE.

We make end-to-end pipelines intelligent and accessible to contextualize the needs from creators and users in applications.