Kinergy

Creating 3D Printable Motion using Embedded Kinetic Energy

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System Setup
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?
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

Non-Periodic Motion Types

- Instant Translation
- Instant Rotation
- Continuous Translation

Periodic Motion Types

- Continuous Rotation
- Reciprocation
- Intermittent Oscillation
- Intermittent Rotation
Harnessing the energy stored in springs

Helical Spring

Spiral Spring

Bars

Compliant Latch

Compliant Latch
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

End-Effector
Spring + Ratchet
3D Body
Lock + Stationary Part

Instant Translation

Instant Rotation
Non-Periodic Motion Types

Press Control

Turn Control
Periodic Motion Types

Press Control

Turn Control
Periodic Motion Types

- Reciprocation
- Press Control
- Turn Control
- Spring + Geartrain
- Stationary Part
- Lock
Periodic Motion Types

Press Control

Turn Control

Intermittent Oscillation
Periodic Motion Types

Press Control

Turn Control
Kinergy User Interface

Rhino 3D Editing Environment
Select a target motion type:

- Non-periodic Motion
  - Instant Rotation
  - Instant Translation

- Periodic Motion
  - Continuous Rotation
  - Revolution
  - Inversion Oscillation
  - Inversion Rotation

Continuous Rotation Kinetic Unit

Step 1: Select the target body for embedding the unit

Motion control method:
- Press
- Turn

Step 2: Select the segment and motion control position

Step 3: Select the position of the end-effector

Step 4: Adjust the motion characteristics
- Speed: Min - Max
- Revolutions: Min - Max
- Energy: Min - Max

- Reverse instant rotation direction
- Add a lock

Rhino 3D Editing Environment
Rhino 3D Editing Environment

- Pull-Back Car 3D Model
- Auto-Generated Lock
- Auto-Generated Transmission Mechanism
- Auto-Generated Spring
- End-Effector

KINERGY DESIGN TOOL

Select a target motion type:
- Non-periodic Motion
  - Instant Rotation
  - Instant Translation
- Periodic Motion
  - Continuous Rotation
  - Reciprocation
  - Linear Translation
  - Linear Reciprocation

Continuous Rotation Kinetic Unit

Step 1: Select the target body for embedding the unit
Step 2: Select the segment and motion control position
Step 3: Select the position of the end-effector
Step 4: Adjust the motion characteristics
  - Speed: Min - Max
  - Revolutions: Min - Max
  - Energy: Min - Max

Add a lock
Preview
Finish
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

Step 1: Select the target body for embedding the unit
Step 2: Select the segment and motion control position
Step 3: Select the position of the end-effector
Step 4: Adjust the motion characteristics
  - Speed: Min - Max
  - Revolutions: Min - Max
  - Energy: Min - Max

- Reverse instant rotation direction

Add a lock

Kinergy User Interface

Pull-Back Car 3D Model
Auto-Generated Lock
Auto-Generated Spring
End-Effector

Kinetic Unit Selection Panel
Auto-Generated Transmission Mechanism
Kinetic Unit Control Panel

Rhino 3D Editing Environment
Non-Periodic Motion Control Panel

Instant Translation Kinetic Unit

Step 1: Select the target body
Step 2: Select the translation axis and the segment
Step 3: Adjust the motion characteristics
   - Displacement: Min → Max
   - Energy: Min → Max
Step 4: Select the end-effector

[Options: Add a lock, Preview, Finish]

Instant Rotation Kinetic Unit

Step 1: Select the target body for embedding the unit
Step 2: Select the rotation axis and the segment
Step 3: Select the end-effector
Step 4: Adjust the motion characteristics
   - Revolutions: Min → Max
   - Energy: Min → Max

[Options: Add a lock, Preview, Finish]

Continuous Translation Kinetic Unit

Step 1: Select the target body for embedding the unit
Step 2: Select the segment and motion control position
Step 3: Select the position of the end-effector
Step 4: Set the translation axis direction
Step 5: Adjust the motion characteristics
   - Speed: Min → Max
   - Distance: Min → Max

[Options: Add a lock, Preview, Finish]

Continuous Rotation Kinetic Unit

Step 1: Select the target body for embedding the unit
Step 2: Select the rotation axis and the segment
Step 3: Select the position of the end-effector
Step 4: Adjust the motion characteristics
   - Speed: Min → Max
   - Revolutions: Min → Max

[Options: Add a lock, Preview, Finish]
Kinetic Unit Enabled Pullback Car Example

Motion Preview

- Lock Head
- Lock Base
- Spring
- Shaft #1
- Shaft #2
- Shaft #3
- End-Effector

Car Model
- Gear #1
- Gear #2
- Gear #3

Spring

Shaft #1
- Gear #1
- Fixation
- Locking

Shaft #2
- Gear #2
- Engagement

Shaft #3
- Gear #3
- Car Model
- End-Effector
Walkthrough:
making a self-popped Mr. Halloween Pumpkin using an instant translation kinetic unit
Fabrication
Tolerance Types

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

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

Printing orientation

**Exclusive** slicing tolerance
A minimal negative **0.04mm**
horizontal expansion
Kinergy Applications
Self-Opening Umbrella

Instant Translation
Kinetic Unit

X2
Accelerometer
Circuit (hidden)
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

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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 environments through sensing, computation, and digital fabrication.

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