Clay for the Creative Mind: Hands-On Robot Shaping Using Truss Links

Philippe Martin Wyder*
Mechanical Engineering Department
Columbia University
New York, NY, USA
Research
Distyl AI
New York, NY, USA
philippe.wyder@columbia.edu

Judah Goldfeder
Computer Science Department
Columbia University
New York, NY, USA
jag2396@columbia.edu

Quinn A. Booth
Electrical Engineering Department
Columbia University
New York, NY, USA
qab2004@columbia.edu

Meiqi Zhao
Computer Science Department
Columbia University
New York, NY, USA
mz2651@columbia.edu

Gaurav Himanshu Patel
Mechanical Engineering Department
Columbia University
New York, NY, USA
ghp2122@columbia.edu

Jiong Lin
Mechanical Engineering Department
Columbia University
New York, NY, USA
jl6017@columbia.edu

Allen Roush
Thoughtworks
Chicago, IL, USA
allen.roush@thoughtworks.com

Hod Lipson
Mechanical Engineering Department
Columbia University
New York, USA
hod.lipson@columbia.edu



Figure 1: Truss Links: A modular robot platform for creative exploration and human-robot co-creation.

Abstract

Truss Links are a modular robot platform originally developed for studying Robot Metabolism, the ability for machines to grow, repair, and intelligently adapt by integrating components from their environment or other robots. Here, we investigate whether Truss Links can be more than robots that build themselves: can they serve as a creative medium accessible to non-experts? In this paper, we present a preliminary research-through-design exploration of Truss Links as digital building blocks for the physical world. We demonstrate how Truss Links can be used to animate text, animate two- and three-dimensional shapes, form kinetic sculptures, and hand-build a delta pick-and-place robot. We discuss what this exploration reveals about the design properties that can make a research-grade robotic platform accessible as a creative medium.

*Also affiliated with Distyl AI

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CCS Concepts

• **Human-centered computing** → **Interactive systems and tools**; *Creativity support tools*; • **Computing methodologies** → **Robotic control**.

Keywords

modular robotics, human-robot interaction, kinetic sculpture, tangible interfaces, creativity

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1 Introduction

Truss Links are a powerful modular robot platform originally developed for studying Robot Metabolism—the ability for machines to grow, repair, and intelligently adapt by integrating components from their environment or from other robots. However, in recent months, Truss Links have gone viral on social media, amassing tens of millions of views[38] for an entirely different reason: Truss Links are reminding people of the Microbots from the movie Big Hero 6. Truss Links inspire imagination.

The unexpected public enthusiasm raises important questions for human-robot interaction and creativity support: can robotic platforms designed for specialized research be reimagined as accessible creative tools? What design properties enable non-expert users to engage meaningfully with reconfigurable robots? And crucially, how could such a platform democratize access to computational creativity and STEM learning in ways that have a positive societal impact? This paper begins to address these questions through a research-through-design exploration [46] that repositions Truss Links from a research platform designed to study *Robot Metabolism*[41] into intuitive, digital building blocks for creative exploration (see Fig. 1). To investigate this accessible modality, we explore four distinct modes of artistic and functional expression: first, animating text by treating words and glyphs as physical objects that move, oscillate, and transform; second, assembling and animating two- and three-dimensional shapes; third, building kinetic sculptures that exhibit coordinated, rhythmic behaviors across simple, repeated elements; and finally, hand-building a delta pick-and-place robot to illustrate how nontrivial mechanisms can be realized quickly without custom fabrication or specialized tooling.

We make the following contributions:

(1) We investigate Truss Links through the lens of research-through-design and articulate the involved design principles: magnetic self-assembly, functional versatility across artistic and utilitarian applications, and non-threatening aesthetics that counter dominant technology narratives.
(2) We demonstrate these principles through four diverse applications: animated typography, 2D/3D shape animation, kinetic sculptures, and a functional pick-and-place robot.
(3) We reflect on what this exploration reveals about the design properties—magnetic self-assembly, functional versatility, and non-threatening aesthetics—that enabled a research-grade platform to serve as a creative medium.

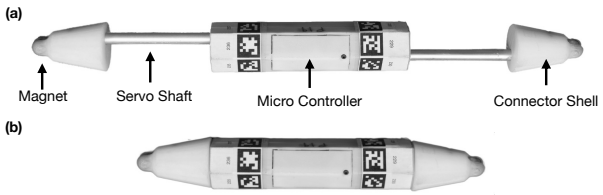


Figure 2: Truss Link overview. Closeup of an expanded (a) and contracted (b) Truss Link.

2 Related Works

Since Fukuda's introduction of dynamically reconfigurable modular robotics [9], research has predominantly focused on optimizing the versatility, scalability, and resilience of the underlying hardware [11]. Iterations on these platforms have explored diverse architectural paradigms, ranging from cellular-inspired self-deforming systems like Morpho [45] to heterogeneous modules featuring reusable electronics [10, 24]. While cubic modular configurations [14, 23, 33, 48] often restrict design freedom due to highly constrained, orthogonal attachment angles, recent developments in free-form connectors—such as FreeSN [39] and FreeBot [22]—and alternative polygonal morphologies [5, 6] have introduced arbitrary-angle attachments. However, across these variations [37, 44, 47], the target domain remains autonomous algorithmic control rather than human-centered interaction.

Parallel to dense modular collectives, truss-based modular robots leverage scaffold structures and prismatic joints to construct sparse lattices. The the Variable Topology Truss [28, 36] exemplifies this robot paradigm, offers improved strength-to-weight ratio, and enables highly efficient geometric configurations. Tensegrity variants combine these rigid elements with compliant, tensile networks [29, 32, 35]. Yet, despite their geometric fluidity during runtime, traditional truss platforms keep their connections static once assembled, lacking the rapid, organic reconfiguration found in other modular collectives.

Truss Links bridge this gap by combining free-form magnetic connectors with an active truss-style architecture (see Fig. 2). Originally introduced by Wyder et al. to study *Robot Metabolism* [40, 41], the platform was designed to investigate how independent, crawling robotic units could exploit environmental topologies to self-reconfigure and self-assemble [43], contrasting sharply with stochastic or single-unit particle systems [4]. While prior literature evaluates Truss Links strictly through the lens enabling robots to self-reconfigure and self-assemble, their structural fluidity and tactile snap suggest an entirely different modality. In this work we venture beyond earlier studies and explore Truss Links as an interactive, tangible medium for creativity and learning.

2.1 Tangible Interfaces for Creativity and Learning

Our work builds on decades of research into tangible user interfaces and their role in learning and creative expression. Ishii's vision of Tangible Bits [18] established how physical forms can give computational information a directly manipulable presence, reducing abstraction and leveraging human spatial and motor skills. Hornecker [15] claims that the power of tangible systems lies not just in intuitive mappings but in their hybrid nature—blending digital computation with physical interaction in ways that support reflection and learning.

In educational contexts, constructionist learning theories emphasize how physical construction activities scaffold abstract reasoning. Tangible programming systems like Topobo [30] and modular robot kits demonstrate how construction activities can make computational concepts concrete[26]. More recent systems explore how reconfigurable tangible interfaces can support collaborative creativity[2, 21, 34]. Jordà et al. introduced the Reactable [19], a collaborative musical instrument built around an interactive tabletop interface that demonstrates how physical manipulation can allow people to be creative and express themselves. The Reactable blurs the boundary between tool and artwork. From the opposite perspective, at the intersection of robotics and aesthetic judgment, Hu et al. [16] demonstrate robots that can be trained to enact human notions of visual tidiness—another instance of robotic systems operating within a human aesthetic framework rather than a purely functional one.

Truss Links forge their own branch in this lineage by deviating from previous designs: cube-shaped modules and robot kits. They combine the constructionist philosophy with an aesthetic that lends itself to artistic expression. Still, their physical properties scaffold abstract reasoning through direct manipulation, just as in Papert's notion of "objects-to-think-with" [27]. They fit Ackermann's model of alternating "diving in" and "stepping back" [1] because they naturally facilitate immersed making and reflective observation. Resnick's creative learning spiral [31] and Kafai's constructionist design framework [20] similarly emphasize iterative cycles of imagining, making, and reflecting as the engine of creative development, all of which are found in the experience of interacting with Truss Links.

Truss Links' magnetic connectors enable haptically satisfying, rapid reconfigurability in a functional robotic package. In their built form, Truss Links' design emphasizes open-ended creative exploration as the entry point, with technical depth emerging through use or even through manual assembly. In this way, Truss Links embody a constructionist design approach: the magnetic snap-together assembly lowers the threshold to building, while the open-ended topology invites users to discover structural possibilities through hands-on play rather than instruction.

3 Exploring Truss Robots as Art

To encourage exploration, we let our team members explore creative uses of Truss Links. The results were varied and plentiful. Here, we present four such explorations: robotic typography, hand-built shapes and structures, robot spinners, and a pick-and-place delta robot. Much inspiration came from the Truss Link's glow-in-the-dark body parts that would emmit a light green hue in the dark and would glow bright when illuminated by UV light (as shown in Fig. 3). Further, Truss Links are easy to handle, connect, and disconnect; thus, exploring new robot designs is easy.

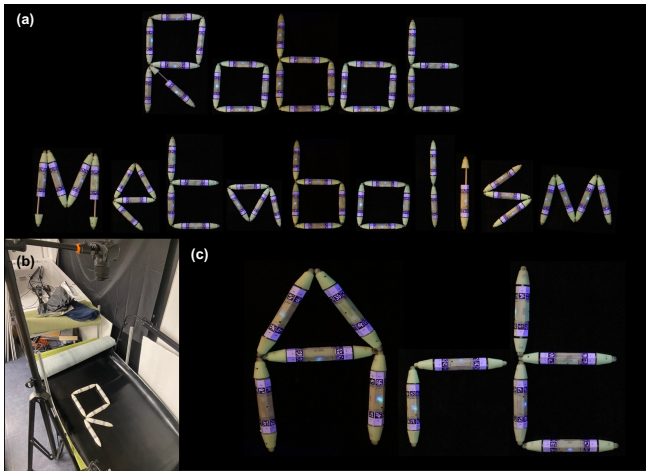


Figure 3: Truss Link letters. (a) The original motivation for developing the Truss Link letters—spelling Robot Metabolism using Truss Links. (b) Each letter was filmed on a sloped, black rubber surface using a top down DSLR camera. (c) Close-up of the word "Art" spelled using Truss Links. Additional letters were created over time.

3.1 System Architecture and Specifications

Before diving into the creative applications, we provide background on the Truss Links system [40]. The Truss Link hardware and software are open source and available on robotmetabolism.github.io. The plastic parts needed to build one Truss Link can be printed in a single print on a regular-sized, consumer-grade FDM 3D printer.

Design Rationale. According to Wyder et al., the platform was designed around off-the-shelf components using commonly accessible tools—soldering iron, FDM printer, and hot-glue gun—to facilitate replication [40]. The 53% expansion ratio, the ratio between the length of a fully contracted and a fully expanded Truss Link was specifically chosen to enable tetrahedron structures to shift their center of mass sufficiently for toppling behavior without collapsing: a geometric analysis revealed that this required at minimum a 41.5% expansion ratio.

The magnetic connectors allow arbitrary-angle attachment without precise alignment. If two connectors are within an inch of each other, they snap together. Inside each connector is a freely-rotating, self-aligning magnet sphere that enables multiple connectors to attach at a single point. In our experiments, we successfully operated topologies with up to four connector connections.

Specifications:

- **Length**: 28 cm contracted, 43 cm fully expanded (53% expansion ratio)
- **Weight**: 280 g per module

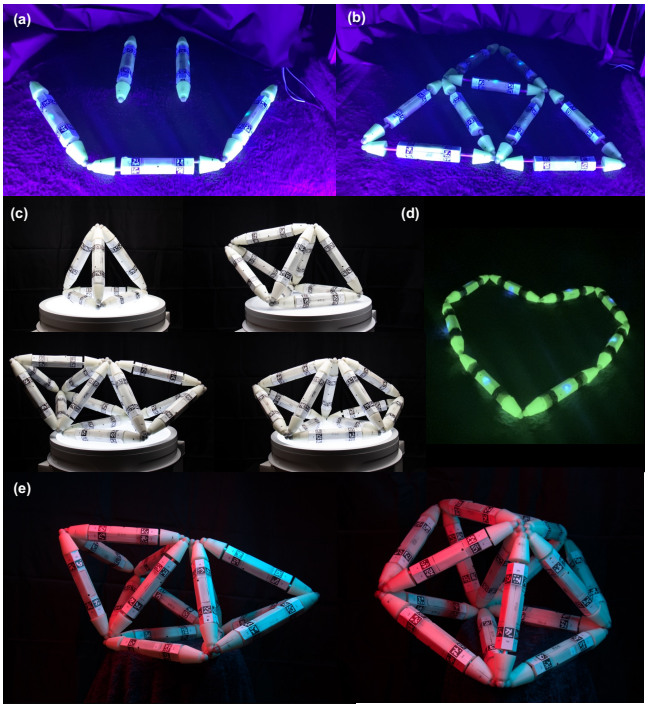


Figure 4: Shapes and structures formed from Truss Links. Truss Link 2D shapes: (a) smiley face, (b) pyramid, (d) heart. (c) shows a frame sequence of a tetrahedron that is being expanded by adding three Truss Links at a time to form a large polyhedron. (e) shows two manually assembled structures the first (left) comprising 15 Truss Links, and the second (right) comprising 16 Truss Links

- **Actuation**: Two Actuonix L-12I linear servos (100 mm stroke, 210:1 gearing ratio)
- **Power**: Two removable 380 mAh single-cell Lithium Polymer batteries (connected in series)
- **Connector**: 12.7 mm diameter N52 neodymium magnet sphere enabling free-form attachment
- **Connection strength**: 13.7 N pull-away force between two connectors
- **Controller**: Particle Photon microcontroller with WiFi antenna
- **Cost**: The Materials to build a single Truss Link cost $220 (the servos are the main cost contributor at a total of $180)

The control architecture of the Truss Links is built around a server script that can be run from a laptop with an operator-controlled keyboard interface and dashboard. The keyboard interface allows the operator to send commands to selected Truss Links or trigger pre-programmed open-loop control scripts (see [41] for more details). Truss Links are equipped with a voltage regulator that steps the battery voltage down to 5V for the microcontroller and a voltage divider that monitors the battery voltage through an onboard 12-bit analog-to-digital converter. Each Truss Link communicates its status via Wifi to the server that allows it to be visualized on the dashboard.

3.2 Development Process and Participants

The Truss Link platform was developed as part of a multi-year project aimed at the study of robots that could "grow" and develop within their lifetime [41]. The explorations reported here were carried out by six undergraduate and graduate students with backgrounds in mechanical engineering, computer science, and electrical engineering. None had prior experience with the Truss Link platform before joining the project. The students were primarily tasked with research on the platform itself; the creative explorations described here arose as side activities, driven by curiosity and play. These took place alongside regular lab work, without prescribed creative tasks or evaluation protocols, and were documented through video recording and informal observation notes. Work was often carried out in pairs. The robotic typography (Section 3.3) and 2D shapes (Section 3.4) originated from creative student initiatives (see Fig. 4). The kinetic spinner (Section 3.5) and delta robot (Section 3.6) were developed out of curiosity—to see whether it was possible.

With the batteries installed and the control interface running, newcomers learned to operate Truss Links within a single session and could make use of the pre-programmed locomotion gaits for triangles, tetrahedrons, and other shapes. This experience stands in contrast to the delta robot, which required custom coding and kinematics calculations. Truss Links proved physically intuitive to handle; a surprising finding, given that usability was not a primary design goal during platform development.

3.3 Robot Typography

The robotic typography exploration originated from a desire to animate the project's name: *Robot Metabolism* (see Fig. 3(a)). Each letterform was manually constructed using one to six Truss Links arranged to approximate the character's structural skeleton, with the links' natural resting posture defining its static geometry. To generate motion, the modules were programmed to cycle through collective expansion and contraction, causing them to predictably shuffle down the gently sloped, black rubber surface captured by a top-down DSLR camera (see Fig. 3(b)). This locomotion strategy allowed us to capture each character individually and manipulate the footage—playing clips forward so letters exit the frame, or backward so they slide into view, or play them in short loops to evoke a breathing effect. The video sequences were initiated under regular ambient lighting for legibility, and then switched to UV lighting to exploit the Truss Links' glow-in-the-dark effect (see Fig. 3(c)) and reducing the letters to luminous, minimalist animated figures moving across a stark, dark background (see supplementary video).

3.4 Shapes and Structures

Similar to the letters, we explored other 2D shapes: a smiley face with an expanding grin (Fig. 4(a)), an expanding flat pyramid (Fig. 4(b)), and a growing and shrinking heart for Valentine's Day (Fig. 4(d)). The satisfying snap of the magnetic connectors and the immediate visual feedback of each added link invited further exploration, and we moved on to three-dimensional structures.

The 3D structures (Fig. 4(e)) were assembled without a prescribed design. We identified stable configurations through trial and error, and human intuition—building a 15-link and a 16-link structure. The

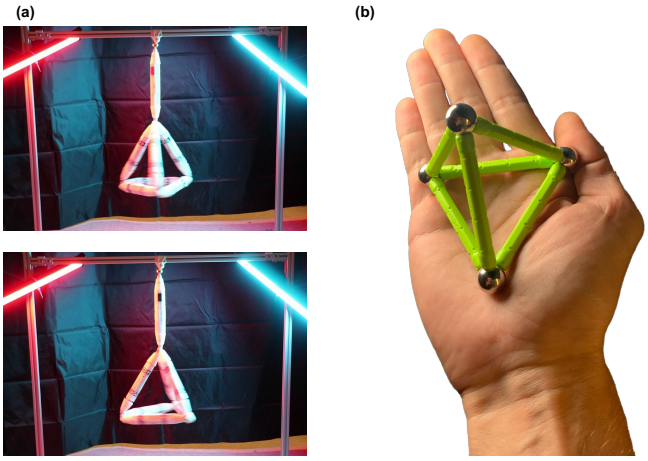


Figure 5: Kinetic and functional Truss Link explorations. (Top) A Truss Link tetrahedron spinner in a dramatically lit environment (a), alongside the Geomag toy that inspired the Truss Link design (b).

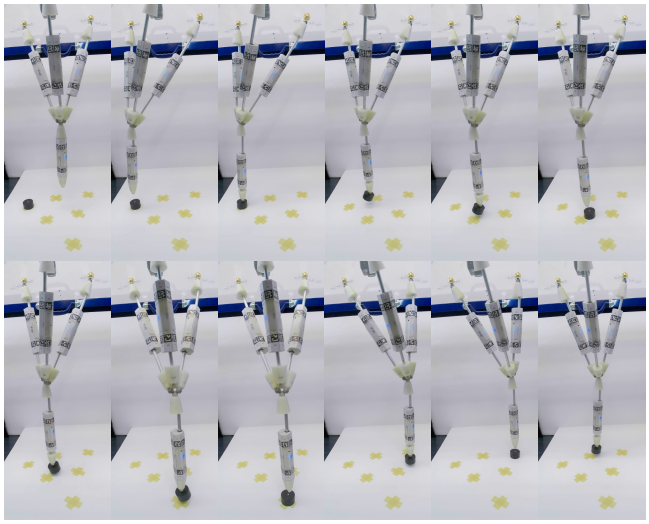


Figure 6: Truss Link delta robot pick-and-place frame sequence demonstrating the workspace.

tetrahedron expansion sequence (Fig. 4(c)) took a more systematic approach: starting from a minimal six-link tetrahedron, we added three links at a time to grow a larger polyhedron step-by-step. This iterative process reveals a key property of Truss Links: because all modules are identical and connectors are free-form, assemblies scale naturally—limited only by the number of available links and the holding strength of the magnetic connectors.

3.5 Robot Spinners

The Truss Link design was inspired by the Geomag toy comprising magnetic sticks and metal spheres[41]. One popular way of playing with Geomag is to shape them into spinners, such as a tetrahedron (Fig. 5) attached to another element with two spheres acting as a low-friction attachment point to hang from. Naturally, we built a tetrahedron shaped spinner, by hanging a tetrahedron on an additional Truss Link that connects to a 1-inch magnet sphere at the top that is mounted to an aluminum frame. The added magnetsphere acts as a low-friction connection and allows the spinner to rotate. We accelerated the spinner by rotating it by hand or via compressed air. We also expanded the spinner as it was rotating to slow the rotation, and then contracted it again to increase the rotation again. However, due to the slow actuation speed of the Truss Link servos the acceleration from contracting is not easily observable in the video.

3.6 Pick-and-place delta robot

The delta robot was assembled from four Truss Links and attacked to three 1-inch magnet spheres that were seated in undersized holes in an acrylic top plate held up by two saw-horses. Three links form the upper delta geometry and a fourth link hangs below as the end-effector. The end-effector link's magnetic connector (see [41] for connector details) was then be used picks up a 45 mm rubber puck fitted with a ferromagnetic threaded insert (see Fig. 5, bottom).

We implemented a Python-based controller that solves forward and inverse kinematics to map keyboard inputs to link lengths in real time. Before applying any motion, the inverse kinematics routine checks whether the resulting link lengths fall within safe mechanical limits. The robot achieves ±2 cm positioning accuracy over a 30 cm × 30 cm × 15 cm workspace.

4 Limitations and Future Work

This work has several limitations that point toward important future directions.

Lack of Formal Evaluation. As an internal research-through-design exploration, this paper does not include controlled user studies or quantitative measures of learning outcomes. While we provide observational evidence from student use, rigorous evaluation of educational impact, learning curves, and creative outcomes on a more diverse set of students remains essential future work. Such studies should compare Truss Links to other modular robotics platforms across diverse user populations, measuring both objective performance metrics and subjective experiences of engagement and empowerment.

Technical Constraints. The Truss Link platform requires refinement to become an effective teaching and study tool. In our explorations, the server software, dashboard, and keyboard interface proved unsuitable for unassisted use by non-technical users—a clear gap between the platform's current state and broader accessibility. Battery changes require a screwdriver and are tedious to perform across multiple links. A more streamlined setup and a true no-code user experience would be needed to make the platform broadly accessible.

Scalability and Cost. At $220 per module, Truss Links are expensive relative to their current DIY-quality level. Future work should

explore lower-cost actuator alternatives or partnerships with educational suppliers and open-source hardware communities to reduce the per-unit cost.

5 Discussion

Truss Links offer tangible accessibility through magnetic connectors that enable rapid assembly without tools or training. Users directly shape robots with their hands and can move them by pushing buttons on a keyboard, bridging the code-hardware divide. In our explorations, tech-savy newcomers readily assembled structures and learned to operate the platform within a single session—an outcome we attribute to the satisfying tactile feedback of the magnetic connectors and the immediate, visible response of the links.

Their functional versatility allows Truss Links to transform from sculptures to working delta robots using identical components. This dual nature—aesthetic and functional—creates a broad entry point: a user drawn in by the aesthetics can, through continued exploration, arrive at surprisingly capable mechanisms. Unlike polished commercial kits such as Cubelets [13], Truss Links are open-source and require tools, assembly, and expertise—a tradeoff that comes at the cost of DIY-grade usability but opens the platform to modification and extension.

Their non-threatening aesthetic offers a counterpoint to more threatening forms of robotics: drones [42], military robots [7], or eerily human looking robot faces [17]. The modular form and visual elements foster curiosity rather than anxiety. The viral social media response—linking Truss Links to the helpful, cooperative microbots from Big Hero 6—suggests the platform resonates beyond specialized research communities, though we note that internet popularity is one signal and not a systematic finding.

The delta robot demonstration (Section 3.6) required custom Python code and kinematics calculations—a non-trivial technical barrier that confined this particular exploration to students with engineering backgrounds. These experiments were conducted before capable coding agents became widely available [3, 25]. We anticipate that such tools will substantially lower this barrier: a user with a creative vision for a Truss Link mechanism could increasingly rely on AI assistance to generate the control code, without needing to understand the underlying kinematics. This points toward a path where the primary constraint on creative robotic exploration shifts from technical skill to creative intent. As AI systems develop increasingly specialized, superhuman capabilities [8, 12], platforms built for physical intuitiveness—like Truss Links—may become genuinely accessible to a much wider range of creators.

Artistically, Truss Links expand kinetic sculpture possibilities through rapid assembly and UV-reactive components. Practically, they retain capacity for pick-and-place tasks and morphological adaptation. This convergence of artistic expression and function blurs boundaries between creative and applied robotics. This preliminary exploration shows the potential of and the need for a platform such as Truss Links. Such a platform could open new possibilities for creative expression: designed, built, and owned by individuals—animating all their creations.

6 Conclusion

This work presents a research-through-design exploration of Truss Links as a creative medium. Through four internal explorations—animated typography, 2D and 3D shape assembly, kinetic spinning sculptures, and a delta pick-and-place robot—we demonstrated that a platform designed for robotics research can serve as an intuitive tangible interface for creative expression. Two design properties emerged as particularly significant: the magnetic connectors, which make assembly haptically satisfying and topology-free, and the software interface, which remains a bottleneck for non-expert users. Addressing this gap—through hardware refinement and AI-assisted programming tools—represents the most promising path toward making Truss Links a broadly accessible creative platform.

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