Demonstration of FlexBoard: A Flexible Breadboard Platform for Interaction Prototyping on Objects

Demonstration of FlexBoard: A Flexible Breadboard Platform for Interaction Prototyping on Curved and Deformable Objects

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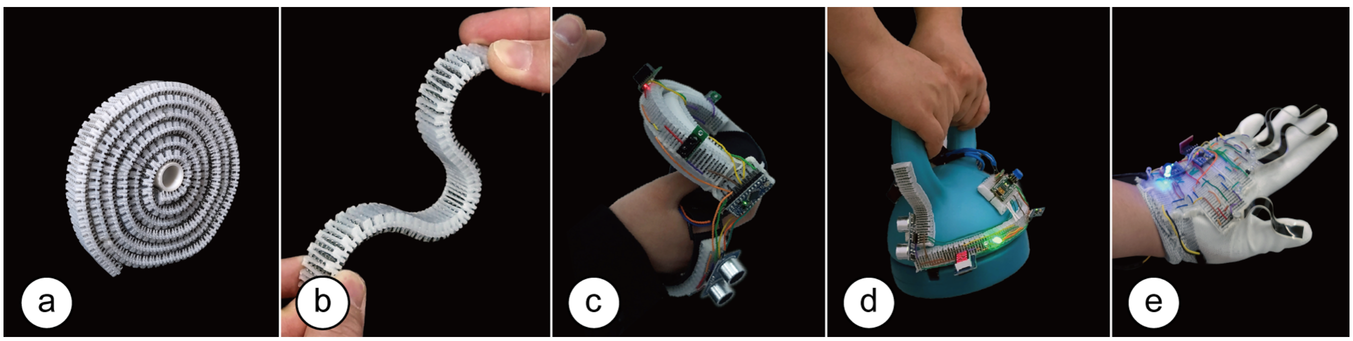

Figure 1: (a,b) FlexBoard is a flexible breadboard that consists of a living hinge pattern with inserted terminal strips. It enables in-situ prototyping on curved and deformable surfaces. Here we used FlexBoard to prototype interactive functionality on (c) the curved body of a VR controller and (d) kettlebell, as well as (e) a deformable glove.

ABSTRACT

We demonstrate *FlexBoard*, a flexible breadboard that enables interaction prototyping with electronic components such as sensors, actuators, and displays on curved and deformable objects. We show how FlexBoard offers flexible and bidirectional bending capabilities to conform to different shapes and materials, including the rapid prototyping capabilities of the traditional breadboard. *FlexBoard*'s bendability is enabled by providing a flexible living hinge instead of the rigid body of a traditional breadboard. FlexBoard holds the metal strips as the traditional breadboard, which can maintain the standard pin spacing for compatibility. In addition, FlexBoards are shape-customizable. Users can cut Flexboard to a specific length and join them together to cover various ranges of prototyping areas. We present the way of fabricating FlexBoard and three application scenarios with interactive textiles, curved tangible user interfaces, and VR devices.

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CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

KEYWORDS

electronic prototyping, breadboards, deformable user interfaces.

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1 INTRODUCTION

Prototyping physical user interface is an essential process for product designers and researchers to explore new user interface designs, test an interactive system in practical use cases, and study the interaction between humans and technology [2, 4]. Building such interactive prototypes often requires the integration of various electronic components into physical objects that can be curved or made of deformable materials. While breadboards are a popular tool for rapid prototyping, allowing users to easily plug electronic components and rapidly rearrange them without the need for soldering, they may not be appropriate for interaction prototyping due to their rigidity.

To address this, researchers developed custom-shaped breadboards that better integrate with prototypes with different shapes and properties. BitBlocks [1] are modular mini-breadboards that can be combined into different 2D shapes, but they are flat and rigid, making them difficult to attach to curved surfaces. CurveBoards [6] are directly integrated into the curved surface of prototypes, but their fixed geometry requires refabricating the entire prototype for repositioning. Jellyboard [5] is a flexible breadboard that can be attached and repositioned on curved geometries, but its bending is limited to one direction and it doesn't preserve the standard pin layout and spacing of a typical breadboard.

In this demo, we introduce FlexBoard [3], a flexible breadboard that can bend upwards and downwards to prototype on curved and deformable surfaces. FlexBoard can be fabricated on an off-the-shelf 3D printer and has standardized pin spacing and terminal line layouts (Figure 1). We first explain how to prototype with FlexBoard and its mechanical design. Then, we describe how to fabricate FlexBoard. Finally, we showcase the usefulness of FlexBoard with three prototyping scenarios.

2 FLEXBOARD

With Flexboard, users can prototype interactive objects that require distributing electronic components on the prototype's surface with complex geometries.

2.1 Prototyping with FlexBoard

Cutting the FlexBoard into Shape: To prototype with FlexBoard, users start by cutting and joining FlexBoards to create a breadboard length and width that matches the prototype geometry and can accommodate the required electronic components.

Prototyping Circuits: Makers can choose to first prototype their circuit, sensors, and other electrical components in a flat form. Subsequently, makers can attach the FlexBoard to the curved or deformable prototype geometry. Alternatively, makers can also start by attaching FlexBoards to the prototype and then insert electronic components.

Attaching FlexBoard to Objects: To attach the FlexBoard to the target object geometry, makers can use double-sided tapes, velcro-tape, or (epoxy) glues by applying the adhesive on the FlexBoard and subsequently pressing the FlexBoard on the prototype's surface. When developing a prototyping platform with fabrics, users can also sew the FlexBoard onto the fabric by looping a thread through the living hinge as illustrated by our deformable glove application (Section 4.3).

2.2 Flexible Bending with Living Hinge Pattern

FlexBoard is based on a living hinge design, which allows it to bend both up and down and thereby adjust to differently curved object geometries.

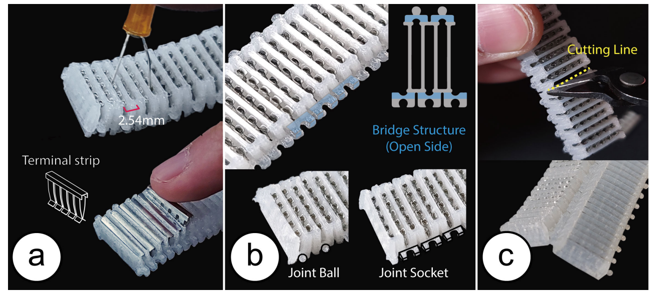

Figure 2: (a) FlexBoards consist of a living hinge pattern, which holds terminal strips. (b) Modifications to the traditional living hinge design. (c) Cutting and joining FlexBoards

Hinges as Holders of Terminal Strips: Each hinge in the FlexBoard hinge pattern represents one terminal strip in a breadboard. To convert a hinge into a terminal strip, we insert one strip into each hinge (Figure 2a). Since the terminal strip's pin spacing is standardized, FlexBoard works with standard electronic components similar to a traditional breadboard. We also maintain the standardized spacing between terminal strips, i.e. hinges are spaced 2.54 mm apart. However, the distance between hinges changes while bending, and thus spacing between terminal columns may change. Users can accommodate this change in spacing by leaving component pins longer or using additional long header pins.

Optimizing the Hinge Design to Hold Terminal Strips: The living hinge pattern of FlexBoard was designed to maintain the overall holding force during bending to keep the terminal strips in place. To accomplish this, we close the previously open side of the hinge by adding a 'bridge structure' (Figure 2b). We place the bridge structure in the middle of the hinge design to enable flexibility both upwards and downwards. The terminal strips are still held in place when bending a single hinge by 12° upwards and 12° downwards, i.e., FlexBoard can bend 360° both downwards and upwards with only 30 segments (7.62cm length).

2.3 Customizing shape of FlexBoards

Users can customize the length and width of FlexBoards by cutting off parts or by joining multiple FlexBoards together.

Adjusting Length by Cutting FlexBoards: Users can create FlexBoards of variable length by cutting a FlexBoard into differently sized pieces depending on the object geometry of the use case. To cut a FlexBoard into a custom length, users only have to cut both sides of the hinge and remove the metal strip (Figure 2c).

Adjusting Width by Joining Flexboards: Users can also extend FlexBoard's overall width by connecting two or more FlexBoards using a ball joint mechanism. We placed a ball structure on the left-hand side of a FlexBoard on top of the bridge structure (Figure 2b) and a corresponding ball joint socket on the right-hand side of a FlexBoard (Figure 2b). This enables not only joining multiple FlexBoards together but also bending individual FlexBoards with respect to each other (Figure 2c) which allows attaching FlexBoards

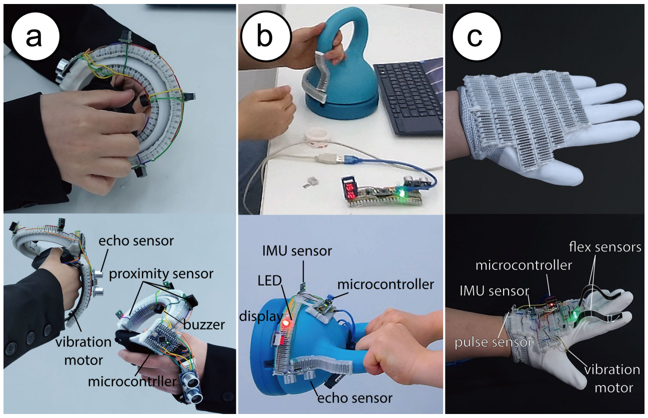

Figure 3: (a) Prototyping a collision warning system for a VR controller. (b) Prototyping an interactive kettlebell. (c) Prototyping electronics on a deformable glove for VR.

on doubly curved surfaces (e.g., for wearables like an interactive VR glove, Section 4.3). The joint structures are designed to offer the same pin spacing, 7.5mm, as on the traditional breadboard, which allows users to plug components with two rows of pins (e.g., IC modules).

3 FABRICATION PROCESS

The fabrication of a FlexBoard involves two steps: (1) 3D printing the living hinge structure, and (2) inserting the power strips into the hinge elements.

3D Printing: To fabricate FlexBoards, we 3D print the living hinge structure on a FDM 3D Printer (Model: Creality Ender-3, nozzle diameter: 0.3mm) with a Vinyl filament (eSun's ePA Nylon Natural). We set the layer height to 0.15 mm in the slicer to preserve the details of the living hinge pattern. The maximum length of a FlexBoard depends on the size of the 3D printer.

Extracting Terminal Strips: We extracted the terminal strips directly from existing breadboards (Adafruit ID:64), i.e. half-size 400 pin breadboards. We peeled off the tape from the backside of the breadboards, which released most of the terminal strips from the board. To extract the remaining strips, we either used our own tape, placed it across the backside of the breadboard, and peeled it off to release more of the terminal strips or used a needle to push the remaining strips out.

4 APPLICATIONS

We demonstrate three application examples that showcase FlexBoard's capability to support prototyping on highly curved or deformable object geometries.

4.1 Prototyping on a Curved VR Controller

When interacting in VR with handheld controllers, users cannot see their own movements and may accidentally hit the walls of a room with the controllers or hit the VR headset. We demonstrate prototyping a collision warning system on a curved handheld VR controller using FlexBoards (Figure 3a).

We attached 3 FlexBoards onto an Oculus Quest 2 VR controller by first cutting them into the right length and using double-sided tape to attach them on the controller. We use a microcontroller (Arduino Pro Micro), an echo sensor to detect collision with walls, and 3 optical IR proximity sensors to detect collisions with the user's body, as well as a vibration motor to warn the user through haptic cues. After wiring all components to the microcontroller we wrote an Arduino Script that triggers the vibration motor when an obstacle gets detected by the proximity or echo sensors.

4.2 Prototyping on a Curved Kettlebell

We used FlexBoard to prototype on a kettlebell to provide users with feedback if a swing with the kettlebell was executed correctly. In addition, the kettlebell counts how often it is swung (Figure 3b).

We started by cutting 2 FlexBoards into the appropriate size for the kettlebell and joined them together using the ball joints, which provided enough space to attach a microcontroller. We then added an IMU sensor to sense the angle of the kettlebell swinging to verify if the kettlebell is held straight, which indicates correct exercise execution. We also added two LEDs (red, green) that indicate to the user if the kettlebell is swinging straight. Finally, we added an echo sensor and a small display to one of the FlexBoards to count and display the number of exercise repetitions. The echo sensor measures the distance to the floor and only counts an exercise repetition if the kettlebell got lifted high enough.

4.3 Prototyping on a Deformable VR Glove

We demonstrate how FlexBoard can be used to prototype electronics on an interactive glove that deforms with the user's hand gestures and that can be used for interactions in VR.

To prototype the glove's functionality, we first cut seven FlexBoards into shape and subsequently joined them together to form one continuous prototyping area. We attached the FlexBoards on the glove by sewing the outer hinges onto the fabric (Figure 3c)). The glove can bend in both upward and downward directions with the FlexBoards attached, which allows the user to execute different gestures.

We used FlexBoard to prototype a VR glove that can be used during VR gameplay. To allow the games to take biofeedback as input, we added a pulse sensor to the glove to detect a user's heartbeat. In addition, to be able to control games with gestures, we added two flex sensors to detect the user's index and middle finger movements and an IMU to detect wrist rotation. To simulate collisions with the user's hand, we added a vibration motor near the user's palm (Figure 3c).

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