MagneShape: A Simple Pin-based Shape-changing Display Using Magnetic Materials

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Abstract

Pin-based shape-changing displays provide dynamic shape changes by actuating numerous pins. However, the large number of actuators required to move so many pins complicates the electrical path and mechanical structure, and creates a need for significant resources if one is to build such a display. Therefore, my research colleague and I proposed a simple pin-based shape-changing display, called MagneShape, that outputs shapes and motions without any electronic components. MagneShape consists of magnetic pins, a pin housing, and magnetic sheet. The magnetic force generated between the magnetic sheet and the magnetic pins levitates the pins vertically. We devised two methods for fabricating alternative magnetic pins, devised a method for controlling the magnetic pins, and developed design tools for MagneShape.

Keywords: shape-changing interface, electronic-free, magnet

1. Introduction

Pin-based shape-changing displays have emerged as computer interfaces for presenting three-dimensional information for physical and haptic interactions [1, 2]. As the name implies, pin-based shape-changing displays have achieved dynamic shape presentation using dozens of pins with electronic actuators. However, as long as an electric motor is used as an actuator for each pin, the mechanical structure and wiring path increase in complexity as the pin array size increases. This issue is also argued in "Grand Challenges in Shape-changing Interface Research" [3], which calls for a toolkit for creating prototypes of shape-changing interfaces that do not require knowledge of electronics or mechanical engineering. Therefore, my research colleague and I aimed to create a shape-changing display with a non-electrical actuation system.

To tackle this issue, we focused on magnetic materials. Magnetic materials are used in many haptic-presentation techniques because they are passive but can generate physical force, and their magnetic polarity can be easily rewritten using a strong magnet [4, 5]. By applying these properties of magnetic materials, we devised a construction method for pin-based shape-changing displays that do not use electric actuators.

2. MagneShape

Our magnetically actuated pin-based shape displays are easy to build, easy to control, and can display characters and quick motions without any linear actuators. MagneShape (**Fig. 1(a)**), our simple pin-based shape-changing display, does not use electronic actuators to move the pins but instead relies on magnetic forces. The basic configuration of the display comprises magnetic pins, a plastic housing, and magnetic rubber sheet. The body of each magnetic pin consists of a plastic straw, and each straw has a small magnet inserted at its lower end. The pins are inserted into the housing to create a pin array. When the magnetic sheet is moved, the magnetic pins in the housing move up and down due to the attractive and repulsive forces generated between the magnetic pins

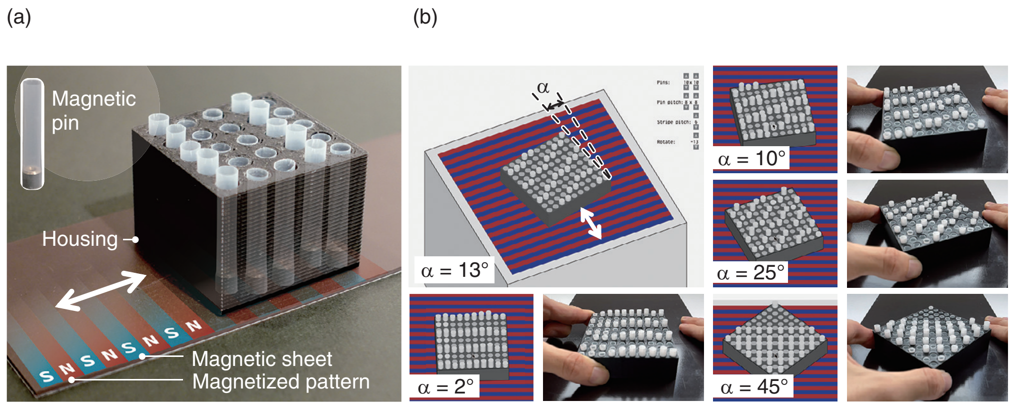

Fig. 1. The basic configuration of MagneShape (a) and comparison of simulation results with actual pin motions (b).

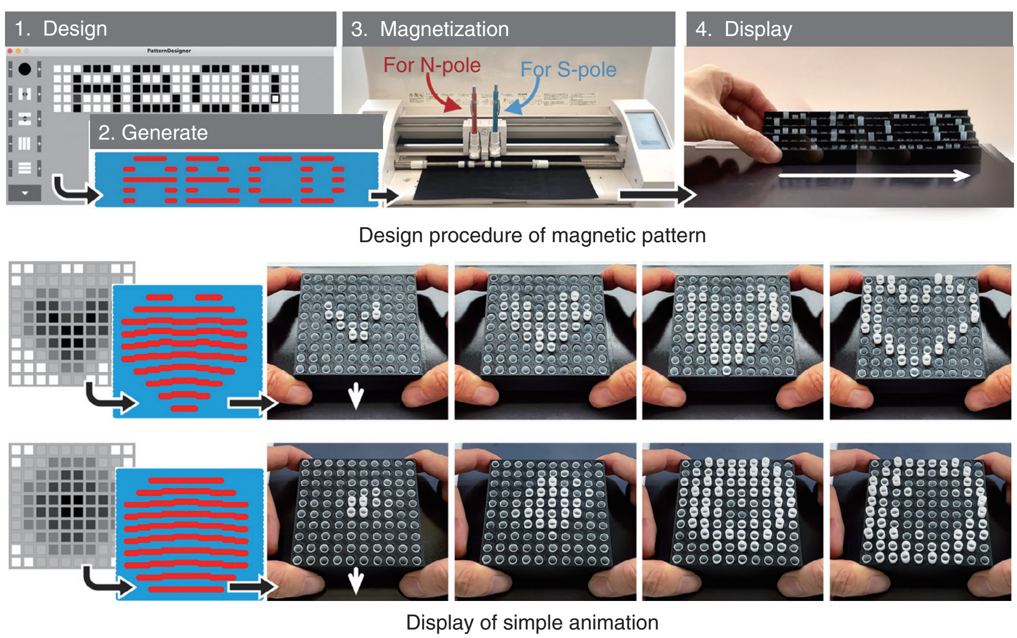

Fig. 2. Design process for magnetic-pattern generation and examples of simple animation presentations.

and magnetic sheet.

We have also implemented design tools for the pin-based shape-changing display. Our pin-motion simulator software allows the user to see how the pins will behave in advance (**Fig. 1(b)**), and our pattern-generation program automatically generates magnetic patterns in accordance with the shapes to be presented (**Fig. 2**). By moving the pin array on a magnetic sheet, it can display characters, flowing waves, a blinking heart, and a circular ripple. For this technique, no wiring, power supply, or programming is needed. This method enables users to design, build, and operate pin-based shape-changing displays without burdensome equipment, a large budget, or deep knowledge of electronics and engineering.

3. Challenges faced in achieving long pin strokes with high resolution

There were several challenges in determining the basic configuration of MagneShape. The first challenge was that posed by magnetic interference

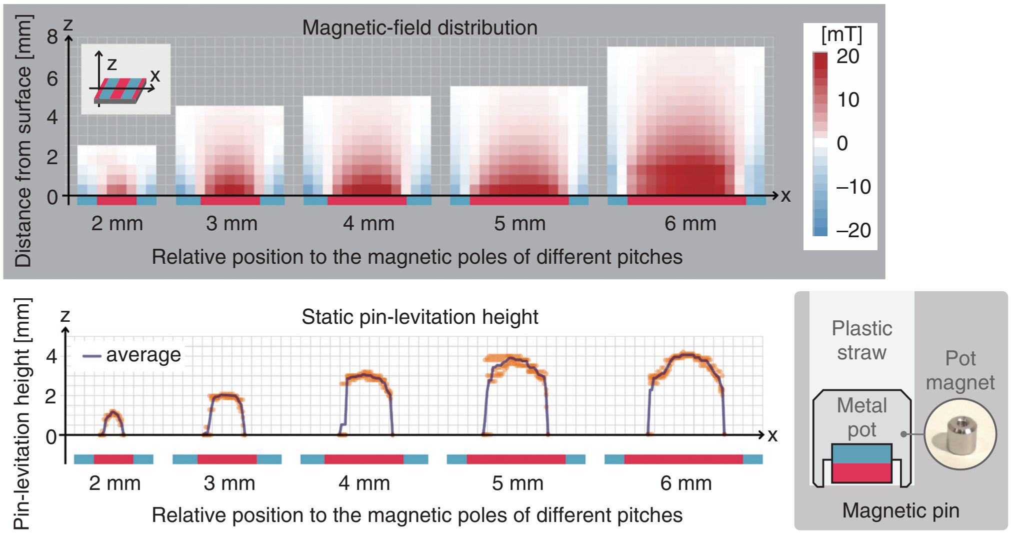

Fig. 3. The spatial magnetic flux density above the different magnetic stripes affects the levitation height of the magnetic pins.

between the pins. The larger the magnet, the stronger the magnetic field emitted, and the stronger the magnetic field, the higher the magnetic pins will levitate. However, if the magnetic fields around the magnetic pins are too strong, the spatial resolution of the pin-based shape-changing display will drop, because too strong a magnetic force will attract or repel magnetic pins adjacent to the one being targeted, causing interference and preventing the independent manipulation of each pin. To counter this interference problem, we used pot magnets in the pins of MagneShape. Pot magnets are fabricated by fixing a permanent magnet into a container called a pot, made of iron or other material with high magnetic permeability. Since the pot prevents the magnetic flux from leaking out from the sides or top of the magnet and concentrates it downwards, the spatial resolution of the pin array is improved significantly by using pot magnets.

We then examined how far the magnetic pins could levitate and how much the levitation height varied, depending on the pitch of the magnetic stripes on the magnetic sheet. We prepared magnetic sheets with 2–6-mm-pitch magnetic stripe patterns, placed the pin array on the magnetic sheet, and measured the levitation height of the five magnetic pins above the N-pole while adjusting the position of the pin array in 0.1-mm steps. **Figure 3** shows the results and average levitation height for the five pins. The pins gradually rose and reached their maximum height just above the centerline of the N-pole, and the maximum levitation height varied from 1–4 mm as the stripe width was changed from 2–6 mm.

However, in proposing this magnetic pin configuration as a component of the prototyping method for a pin-based shape-changing display, a problem presents itself in the small size range of commercially available pot magnets. Therefore, we devised two methods for fabricating alternative magnetic pins. The first method, which we called the *punch-sheet* method, uses a magnetic sheet and hole puncher or leather punch tool. The other method, which we called the *pot-like* method, involves building a pot-like structure by assembling some off-the-shelf parts. Although users need to assemble materials and craft them to make magnetic pins, these methods enable the creation of pins in various sizes, weights, and magnetic strengths. We created 23 different sizes of magnetic pins using these methods and investigated the minimum pin pitch across all of them. We then selected two alternative magnetic pins that functioned effectively when the margin between pins was equivalent to that in the array made with pins using commercially available pot magnets and measured the maximum dynamic levitation height for both of these two alternative magnetic pins. The measurement results reveal that the alternative magnetic pins reached maximum dynamic levitation heights of 16–20 mm when the pin array housing was moving at 80 mm/sec (**Fig. 4**). The pin stroke of the pin is thus significantly improved by using the alternative

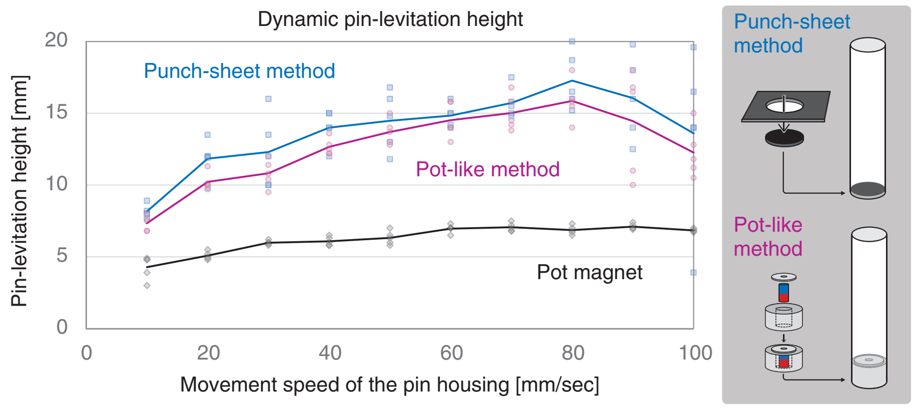

Fig. 4. The alternative magnetic pins produce significant improvements in dynamic levitation height compared with pins made with pot magnets.

magnetic pins.

4. Conclusion

We presented MagneShape: a simple pin-based shape-changing display that is easy to design, assemble, and operate. We also devised a method for controlling the levitation height of magnetic pins and developed design tools for the display. Using these design tools, MagneShape can present characters, a variety of waves, and simple animations.

To enable an increase in pin density within the array, we used pot magnets in the magnetic pins, which significantly improved the spatial resolution of the pin array. To address the generalizability of the magnetic pin concept, we devised two methods for fabricating alternative magnetic pins and found that some of such pins enable a much greater pin-levitation height than those made with pot magnets.

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