Using Shape-Changing Interfaces to Foster Inclusive Education for Visually Impaired People

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Abstract
Shape-changing interfaces contribute to inclusive education for visually impaired people by improving the communication between students and the system through tactile feedback. In addition to touching a screen or pressing a button, students can fold, squeeze, and twist graspable physical elements to understand learning content in an enhanced way. By reading texts and listening to audio captions, students can grab physicalized numbers and perceive the results of science experiments in a tactile way. In this paper, we review shape-changing interfaces and envision how they can be used for inclusive education.

Author Keywords
Inclusive education; shape-changing interfaces; STEM; reading

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Introduction
Shape-changing interfaces – whether manually deformed by users or automatically actuated by systems – can convey a lot more information than screens through changing their shapes, texture, or

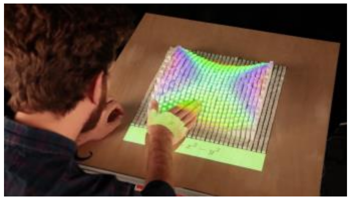

Figure 1. inFORM [3] is physically rendering $z=x^2-y^2$ graph. Users can touch over the surface and feel how the equation would look.

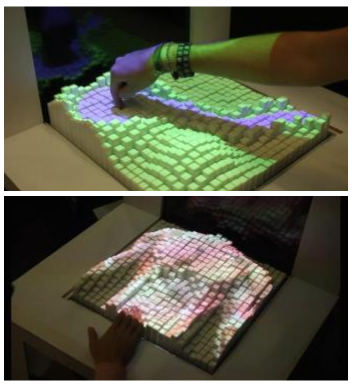

Figure 2. With Materiable [11], users can press pins and feel different viscosity depending on the material that the pins are rendering. (Upper) a user is pressing a water part on a rendered 2.5D geography. (Lower) a user is pressing a physically rendered human body model. Different organs have different viscosity. For example, Bones are hard and intestines are elastic. Users can learn locations of organs and their physical properties.

stiffness. Although they can potentially benefit visually-impaired users, a low number of research projects have investigated it. In this paper, we reveal possible contributions of shape-changing interfaces for visually impaired people within the context of inclusive education. We review recent literature on shape-changing interfaces and discuss how they can be used in inclusive education for visually-impaired people.

Taking Form Factors and Interactions of Everyday Deformable Objects

Interfaces with form factors of everyday objects tell users how to deform them as an input. The familiarity reduces learning time for new interfaces and gives confidence to users. In one of our previous works, we show that there are many shape-changing interfaces using objects that users are familiar with [7]. For instance, Lee et al. [9] investigated future foldable display using daily objects such as newspapers and umbrellas. Users change the size of the display by folding the map or turn off the display by completely folding the umbrella. For visually impaired people, the deforming actions can change text-to-speech engine speed, volume, or content. Additionally, a sheet of paper [13], a piece of fabric [14], a book [4], an ancient scroll [6], a Rubik's Magic puzzle [12] and a Rubik's cube [15] were also used to design shape-changing interfaces. Their deformations were used to navigate information [4, 12,13,15] change display settings [6,9], or convey emotions [14].

Richer Haptic Feedback and Dexterity with Shape-Changing Interfaces

On the other side of deformable objects, there are shape-changing interfaces, which are automatically actuated and change their forms. They can provide richer haptic feedbacks than vibrations, through changing their shapes [3,10,16], texture [16], or stiffness [2]. Interacting with them involves more dexterity, such as squeezing [8], twisting [1], than touching or clicking. The haptic feedback and dexterity can not only increase the information bandwidth that a system can convey to users but also help them develop motor control skills when are young.

Physicalizing Information with Actuated-Pin Interfaces

Actuated-pin interfaces are similar to braille, but they normally consist of thicker pins (~1cm X 1cm in inFORM) and can travel higher (~10cm in inFORM). Although they may not be useful for braille, they can be used for various applications. They can change the shape and volume with the extended pins. They can provide dynamic material properties such and be used in mobile context [4]. Here we discuss inclusive educational applications with those interfaces.

- **Algebra**: The interfaces can be first used to educate numbers, from counting to four fundamental arithmetic operations. Each pin can come up from the surface represent number "one." They can be used to show the operational concepts and let students calculate solve problems on it.
  In addition, the interface can represent graphs (see Figure 1). It will help students to understand how an equation can be drawn as a graph.
- **Science Experiment**: school science experiments often involve with dangerous materials, and the results are only visually observable. The actuated-pin interfaces can render visual changes physically, jointly with a depth camera [10]. For instance, Materiable [11] shows how actuated-pin interfaces

can be used for simulating material properties of solids and liquids with different viscosity (see Figure 2).

- **Storytelling**: Such devices can render simple 3D shapes such as mountains, buildings, animals. It will help the visually-impaired students learn shapes, sizes, and movements of things in a story.
- **Reading**: An actuated-pin based mobile edge display [4] showed navigating within a smartphone screen using actuated-pins on the side of the smartphone. Instead of navigating on a screen, a future study can use the interface to use text-to-speech engine. For instance, the interface can physicalize structure of the content as many of visually impaired people want structure overview [1]. It can allow students to click a part that they want to jump to. As written text is still the main source of information and learning, increasing reading efficiency will benefit many students.

Conclusion

In this work, we presented a set of potential use cases of shape-changing interfaces for inclusive education driven for students with visual impairments. Shape-changing interfaces like actuated-pin interfaces offer possibilities to support teaching and learning of STEM (Sciences, Technology, Engineering and Mathematics) and reading activities to those pupils who cannot rely on regular visual materials. Beyond touching and clicking, interaction models can be enriched with more dynamic haptic feedbacks, also full dexterities such as squeezing or twisting. We envision that those interfaces can boost the students learning and develop their motor control skills.

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