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Drawing Erasable Tactile Diagrams on Tacilia

Tigmanshu Bhatnagar
UCL Interaction Centre
University College London.
London, United Kingdom
t.bhatnagar.18@ucl.ac.uk

Vikas Upadhyay
School of Information Technology
Indian Institute of Technology
Delhi, New Delhi, India
vikas.upadhyay@cse.iitd.ac.in

Anchal Sharma
Department of Design
Indian Institute of Technology
Delhi, New Delhi, India
anchalsharma@design.iitd.ac.in

PV Madhusudhan Rao
Department of Design
Indian Institute of Technology
Delhi, New Delhi, India
pvmrao@design.iitd.ac.in

Mark Miodownik
UCL Mechanical Engineering
University College London
London, United Kingdom
m.miodownik@ucl.ac.uk

Nicolai Marquardt
UCL Interaction Centre
University College London
London, United Kingdom
n.marquardt@ucl.ac.uk

Catherine Holloway
UCL Interaction Centre and
Global Disability Innovation Hub
University College London
London, United Kingdom
c.holloway@ucl.ac.uk

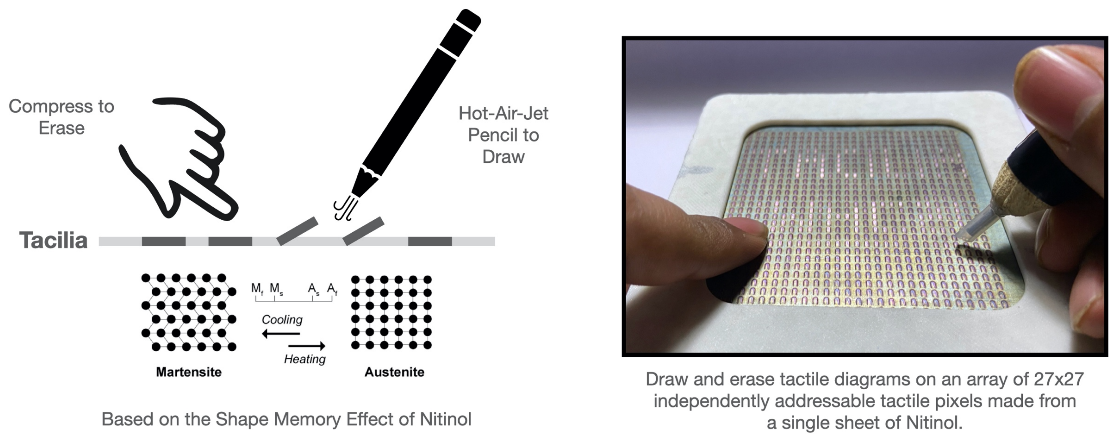

Fig. 1. Tacilia is a reconfigurable tactile pixel array actuator. It working principle is based on the shape memory effect of Nitinol. Combined with a hot-air-jet pencil, it can work as an erasble tactile drawing interface. Low resolution tactile diagrams can be created and erased directly on Tacilia.

***Abstract*— Advances in design using shape changing materials creates a unique opportunity for new haptic interactions. In this demonstration, we will present how a single sheet of Nitinol which is transformed into a reconfigurable tactile pixel array at Braille resolution can be used to read, draw and erase tactile diagrams. We call this interface Tacilia. Tactile drawing is facilitated through a hot-air-jet pencil which provides an intuitive manual control. Drawings can also be erased manually by compressing the pixels with fingertips or with the help of a plastic block. We observed that users instinctively develop unique autodidactic ways to draw and erase directly.**

Keywords—Tactile devices and display; Actuators; Art and entertainment applications.

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I. Introduction

Drawing is a popular medium to communicate ideas despite it being a complex process that requires coordination of kinaesthetic and visuo-spatial intelligence. Due to its kinesthetic nature, the perception of space which a drawing creates is also possible through touch [1]. It means that people with visual impairments who primarily rely on the sense of touch to acquire information can also draw and understand two-dimensional representation of space. Furthermore, drawing can be of equal importance for them, as it is for their sighted peers, in areas of scientific thinking, learning and creativity [2].

At present, there are a few tactile interfaces with which students with visual impairments can draw to learn and express themselves. Manual tactile drawing mediums typically use plastic films which are easy to use and are robust. However, drawings on such mediums cannot be easily erased, leading to an increased dependency on the constant supply of these consumable sheets for regular classwork and practice.

Furthermore, as mistakes cannot be erased, it becomes difficult to practice and iterate. Therefore, in practice, teachers draw on these sheets and use them as passive mediums for the students to read and learn visual concepts. This limits the active participation of students in creating or practicing what is being taught.

Tacilia is a passive reconfigurable tactile pixel array (at Braille resolution) made from a single sheet of Nitinol. In this demonstration, we utilize it as a passive tactile display on which users can manually draw and erase low resolution tactile diagrams. Drawing on Tacilia is facilitated through a hot-air-jet pencil and the drawings can be erased by manually compressing the pixels to their flat state. The interface allows users the freedom to create and learn from mistakes which we envision to be helpful in the education of students with visual impairments.

II. Tacilia – The Tactile Display

Actuation of the pixels in Tacilia is based on the Shape Memory Effect of Nitinol (an alloy of Ni and Ti). For our proof-of-concept, we use the sheet of Nitinol from *Fuxus*® with 51% Ni, an activation temperature of 40±5ºC, and dimensions of 100x100x0.3 mm. An array of 27x27 cantilever U-shaped tactile pixels on the sheet are cut by a laser and are trained to bend out-of-plane when they are selectively heated above the material's activation temperature. Details of this procedure are provided in our technical paper. As a result of training, the material memorizes the bend state of the pixels and snaps to it whenever the pixels are heated. The pixels rise an average of 0.4mm out-of-plane so they are individually perceivable by the fingertips. Their peak blocked force is 0.28kg at 50ºC and 0.23kg force at room temperature after cooling. This blocked force at room temperature is sufficient so that the pixels are perceivable while reading [3]. The nominal rate of cooling at room temperature is 3.61ºC/s and when the temperature of the pixels drops to 38ºC, they can be manually reconfigured back to their flat state by applying a compressive force for repeatable actuation.

III. Hot-air-jet Pencil

Drawing directly on Tacilia is facilitated by a hot-air-jet pencil. Users can intuitively operate this interface to manually actuate targeted pixels and therefore create tactile drawings directly on the array. Its mechanical design is inspired by the double barrel vacuum tube to insulate the fingers that are holding the pencil from the heat that is required to actuate the pixels. Air is pumped through the inner barrel of the pencil which contains a 15W Nichrome heater. The heater heats up the incoming air that exits through a nozzle, which is the tip of the pencil. It is covered with an extended silicone tube to avoid physical contact with the fingertips. The tube also helps to maintain a gap of 0.5 mm between the pencil and the actuating surface to accommodate the bending of the pixels. Furthermore, it concentrates the heated air over the target, minimizing the spread and leak of the hot jet.

At 5V, the air pump generates 380mmHg pressure at the exit of the nozzle. In 30 seconds, the temperature of hot air exiting through the nozzle reaches around 120ºC which instantaneously actuates the pixels in its target. The average time for targeted actuation (from 5 randomly selected pixels) is 0.6s whereas for drawing, it takes an average of 1s for a pixel to actuate.

IV. Tactile Drawing and Erasing

Drawing techniques combines actions of actuating the pixels, perceiving them and erasing the errors. In general, the tactile drawing interaction on Tacilia is slower than pen and paper based sighted drawing. It requires users to observe the behavior of the interface and adapt to the speed and capabilities of the current proof of concept. On the other hand, erasing is straightforward, fast and intuitive as manually applied compressive force on the sheet is sufficient to press the pixels back to their flat state.

Distinct autodidactic techniques to draw can be observed. In the first technique, user perceives tactile feedback only from the pencil as gentle deformation of the compliant silicone nozzle creates a low frequency vibration while the user moves the pencil over actuated pixels. This provides a confirmation of the pixel's actuation. However, this feedback in combination with the kinesthetic motion of the hand, is insufficient to determine the accuracy of the drawing. Therefore, intermittent pauses in the drawing have to be made to perceive what has been created and to erase any errors. In the second technique, users slowly glide over the pixels while the fingertips of the other hand trail behind, giving continuous feedback of what has been drawn. It is also combined with intermittent pauses to erase errors. Synchronous motion of the two hands is observed to provide a higher control and accuracy of drawing, however it is slower than the previous technique. Drawing and reading straight lines and rectilinear shapes is easier and faster than curves and diagonal lines. Confusion persists in perceiving non rectilinear shapes due to the zig-zag nature of diagonals and curved lines at Braille resolution. Furthermore, reading outlines of shapes is clearer than reading filled shapes. The immediate tactile contrast between the actuated pixels and the flat surrounding makes identification and perception of the shapes through their outlines easier.

V. Conclusion

Tacilia is a tactile actuator array which can be used as an erasable tactile drawing interface when combined with a hot-air-jet pencil. Simple tactile diagrams can be drawn and erased using this interface repeatedly. We envision this interface to be beneficial for visually impaired students once its speed and accuracy are optimized.

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