Learning from 3D puzzles to inform future interactions with deformable mobile interfaces

Raf Ramakers
Hasselt University
tUL - iMinds
Expertise Centre for Digital Media.
Wetenschapspark 2, 3590
Diepenbeek, Belgium
raf.ramakers@uhasselt.be

Kris Luyten
Hasselt University
tUL - iMinds
Expertise Centre for Digital Media.
Wetenschapspark 2, 3590
Diepenbeek, Belgium
kris.luyten@uhasselt.be

Johannes Schöning
Hasselt University
tUL - iMinds
Expertise Centre for Digital Media.
Wetenschapspark 2, 3590
Diepenbeek, Belgium
johannes.schoening@uhasselt.be

Abstract
Nowadays, an increasing number of people use ensembles of differently sized mobile devices to accomplish different tasks. With advances in display and input technologies, such as flexible and deformable OLED and E-ink displays, we can close the gap between different form factors and offer devices that can be deformed and transformed for different purposes. In this paper, we explore 3D puzzles in terms of interaction and engineering principles to inform future deformable mobile interfaces. 3D puzzles offer unique transformations between 2D and 3D shapes. These puzzles are designed to stimulate exploration of many shapes and the transformations between them. We think that our exploration can help to inform future directions for deformable mobile interfaces.

Author Keywords
deformable user interfaces; tangible user interfaces, 3D mobile user interfaces; touch interaction

ACM Classification Keywords
H.5.2 [Information interfaces and presentation: User Interfaces]: Input devices and strategies

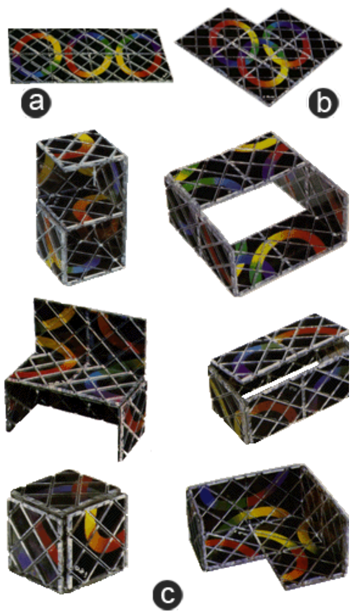

Figure 1: 2x4 Rubik's Magic folding plate puzzle: (a-b) Start-end configuration; (c) Various 3D shapes.

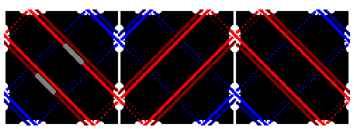

Figure 2: Wiring technique to realize the hinges.

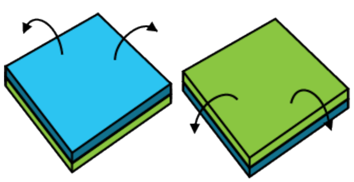

Figure 3: The location of the two hinges is different when the tile is above or underneath another tile.

Introduction & Motivation

Today most of the interactive devices have a certain size and shape. This leads to a portfolio of devices ranging from nano devices, mobile devices, phablets, tablets, laptops to interactive surfaces of any size (e.g. Apple's iPod, iPhone and iPad ensemble). The large need for different form factors of devices makes it impossible to carry a suitable form factor with us for every task. However, innovations in flexible sensors and actuators allow us to dynamically adapt the form factor of devices. As a result, one can imagine a single device that can be deformed to provide the right screen real estate and affordances to fit the task at hand [11].

Advances in flexible display technologies, such as organic light emitting diode (OLED) and thin E-ink displays, enable interaction possibilities, such as folding [4], bending [7] and rolling [5]. Additionally, 3D construction kits, such as Topobo [10], enable children to assemble their own toys with which they can record and playback movements. These rich and expressive types of direct manipulation utilize the innate capabilities of our hands more than traditional touch interfaces and thereby enable new interaction possibilities. Researchers also explored new opportunities for providing output using deformations. For example, thriftyFaucet [12] and inflatableMouse [6] show how actuators can be used to attribute objects with lifelike qualities in order to convey information through physical changes. Lumen [9] and Tilt Displays [1] use actuation to realize the idea of a 3D display.

In this paper, we investigate how 3D puzzles can inform the design of future deformable devices. 3D puzzles have already existed for centuries, thus capturing a vast amount of design knowledge build up over many years. Clever mechanisms have been engineered to enable complex transformations in 2D and 3D space in order to make these puzzles interesting and challenging. By presenting a scenario, we will show that design concepts used for 3D puzzles can guide the design of future deformable devices and give rise to novel interaction possibilities.

Learning from 3D Puzzles

3D puzzles consist of mechanically interlinked pieces. Many of these puzzles of which the Rubik's Cube is the most well known exist. In this paper, we focus on the Rubik's Magic design, which is a folding plate puzzle. The goal of the game is to transform the tiles until the pictures on the different tiles together form an interconnection of rings (see Figure 1-b). Unlike many other 3D puzzles (such as the Rubik's Cube), the Rubik's Magic enables us to create 3D as well as 2D shapes (see Figure 1-c). The original design of the puzzle consists of a loop of square sized tiles which are held together by wires. A special wiring technique (see Figure 2), where every wire runs diagonally across the tiles, ensures that every tile can hinge along either of two adjacent sides. The location of these hinges is different when a tile is on top or underneath another tile (see Figure 3). This technique is an extension of the Jacobs Ladder folk toy principle[1] and offers the illusion that pieces can be folded in any direction and switch places. The unique engineering principles used here enable the creation of an endless number of 3D shapes as well as various 2D shapes (see Figure 1-c). Many variations of this folding plate puzzle have been created over time. Some of them use different wiring

[1] http://en.wikipedia.org/wiki/Jacob's_ladder_(toy)

Figure 4: The 2x4 Rubik's Magic folding plate puzzle enables various form factors for mobile devices.

patterns (i.e. connecting every tile to one, two or more adjacent tiles), others use different shapes (e.g. triangles, hexagons) or a different number of tiles.

Clever mechanical constructions, such as the wires in the Rubik's Magic, make it possible to transform these kinds of puzzles in surprisingly different ways. The rich deformable properties of 3D puzzles form the basis for the challenging nature of these games. 3D puzzles like the Rubik's Magic support transformations from 2D to 3D which would require more folds when using a paper-like interface [3, 7]. Therefore, looking at the interaction and engineering principles of 3D puzzles provides a unique perspective that can be useful for the design of future deformable devices. For example, one can imagine a device that can be transformed in various shapes (e.g. a mobile phone, tablet, watch or game controller) to provide the right screen real estate and affordances to fit the task at hand.

Scenario

To illustrate the benefits of a device that can be manipulated much alike a 2x4 Rubik's Magic folding plate puzzle, we present the following scenario (see Figure 4). Notice that all transformations are done using a single device.

Adam, an IT manager, is on a business trip in Paris. Before his first meeting, he wants to have a short run through the city. (a) He takes his new deformable mobile device, called *PaDDLE* (Puzzle Device DeformablLE), out of his pocket. In its current state, the device is compact and fits into any pocket or bag. (b) He unfolds the device to have a bigger screen to plan his jogging route. (c) After planning a nice 10 km run along the Seine, he deforms his device, with two simple folds to an armband on which his GPS location, his current speed, a music player and a timer are displayed. In this stage he can perform interactions like the ones proposed by Lyons et al. [8]. By turning the PaDDLE, he can skip through music tracks.

Close to Notre-Dame, Adam gets an important phone call from a client he will meet today. (d) He can easily take off his armband and transform it to a phone. (e) During the call they arrange a time for a meeting in the city and Adam continues the run. Back in the hotel, he takes a shower and notices that he has some time left until the tram arrives. (f) He quickly deforms the PaDDLE into a mobile gaming platform and plays a round of his favorite game. In between, Adam can peak at incoming messages by simply unfolding one part of the screen.

Discussion & Future Work

The scenario presented above nicely highlights the benefits we can gain when using deformation principles from 3D puzzles in mobile devices. In contrast to paper-like interfaces [3, 7], which are based on origami folding techniques, 3D puzzles such as the 2x4 Rubik's Magic folding plate puzzle, can more easily be deformed in various 2D and 3D shapes. This enables us to combine interaction concepts presented by other researchers, such as interactions with wrist-worn [8] and foldable [4] systems.

When using concepts from 3D puzzles in mobile devices, a large variety of form factors can be supported. These different form factors can help to support tasks in different contexts (e.g. viewing a map on a tablet-sized display and transforming it to a wristband during jogging). Furthermore, when function equals form [13], devices become easy to interpret and can be understood directly from their appearances. These visual cues, referred to as affordances, are crucial to our understanding of the world.

In the future, we want to further explore how the different types of transformations supported by 3D puzzles can inform interactions with deformable interfaces. We are currently building a working prototype of PaDDLE by using an Optitrack system to track the different tiles in order to augment them by means of projection. The complex transformations supported by 3D puzzles also provide an opportunity to study how people interact with objects that can be transformed in ways that are unfamiliar to them. These kinds of studies will be essential when computing devices start to be made out of programmable matter [2]. We are also exploring how to ease the sometimes tricky transformations for users. As seen in Figure 1, there are numerous possibilities to transform a 2x4 Rubik's Magic folding plate puzzle. Actuation can be used to assist users or to perform transformations between shapes automatically. The unique assembly of folding plate puzzles provides a unique opportunity to integrate actuators, such as shape memory alloy wires, seamlessly in the design.

References

[1] Alexander, J., Lucero, A., and Subramanian, S. Tilt displays: designing display surfaces with multi-axis tilting and actuation. In *Proc. MobileHCI '12*, 161–170.

[2] Goldstein, S. C., Campbell, J. D., and Mowry, T. C. Programmable matter. *Computer* (2005).

[3] Huang, Y., and Eisenberg, M. Easigami: virtual creation by physical folding. In *Proc. TEI '12*, 41–48.

[4] Khalilbeigi, M., Lissermann, R., Kleine, W., and Steimle, J. Foldme: interacting with double-sided foldable displays. In *Proc. TEI '12*, 33–40.

[5] Khalilbeigi, M., Lissermann, R., Mühlhäuser, M., and Steimle, J. Xpaaand: interaction techniques for rollable displays. In *Proc. CHI '11*, 2729–2732.

[6] Kim, S., Kim, H., Lee, B., Nam, T.-J., and Lee, W. Inflatable mouse: volume-adjustable mouse with air-pressure-sensitive input and haptic feedback. In *Proc. CHI '08*, 211–224.

[7] Lahey, B., Girouard, A., Burleson, W., and Vertegaal, R. Paperphone: understanding the use of bend gestures in mobile devices with flexible electronic paper displays. In *Proc. CHI '11*, 1303–1312.

[8] Lyons, K., Nguyen, D., Ashbrook, D., and White, S. Facet: a multi-segment wrist worn system. In *Proc. UIST '12*, 123–130.

[9] Poupyrev, I., Nashida, T., Maruyama, S., Rekimoto, J., and Yamaji, Y. Lumen: interactive visual and shape display for calm computing. In *Proc. SIGGRAPH '04*, 17.

[10] Raffle, H. S., Parkes, A. J., and Ishii, H. Topobo: a constructive assembly system with kinetic memory. In *Proc. CHI '04*, 647–654.

[11] Rudeck, F., and Baudisch, P. Rock-paper-fibers: bringing physical affordance to mobile touch devices. In *Proc. CHI '12*, 1929–1932.

[12] Togler, J., Hemmert, F., and Wettach, R. Living interfaces: the thrifty faucet. In *Proc. TEI '09*, 43–44.

[13] Vertegaal, R., and Poupyrev, I. Introduction. *Commun. ACM 51*, 6 (2008), 26–30.