Inflated Roly-Poly

Hyosun Kwon, Seok-Hyung Bae, Hwan Kim, Woohun Lee
Department of Industrial Design
Korea Advanced Institute of Science and Technology
291 Daehak-ro, Yuseong-gu, Daejeon 305-701, Republic of Korea
{hyosun.kwon, seokhyung.bae, hwan.kim, woohun.lee}@kaist.ac.kr

ABSTRACT
We present an air-contained display medium that can be directly deformed and spatially moved by various physical interaction techniques for interactive games. We first investigated familiar objects in our everyday lives that allow users to easily anticipate the idea of exertion interaction. We then introduce a novel concept of interactive medium, dubbed *Inflated Roly-Poly*, which consists of an inflated body with a roly-poly structure. This device receives physical input, provides passive haptic feedback and allows spatial interaction. We discuss a number of interaction techniques with game applications on Inflated Roly-Poly that presents an engaging experience through full-body interaction. Finally, we conducted an experience workshop with four participants. The workshop proved that an inflated screen coupled with a roly-poly structure exceeds the capabilities of the rigid touch screens in terms of engagement in physical interaction.

Author Keywords: Inflatable, Exertion Interface, Flexible Displays, Organic User Interface, Embedded Interaction, Physical Interaction

ACM Classification Keywords: H.5.2 [Information Interfaces and Presentation]: User Interfaces─Haptic I/O, Input devices and strategies, Interaction styles, Prototyping;

General Terms: Design, Human Factors

INTRODUCTION
Although a touch screen allows more intuitive manipulation compared to a keyboards and a mouse, there still exist limitations with haptic feedbacks that we take for granted when interacting with real-world objects. Especially in entertainment and game scenarios that require physical effort of bodily action, the user faces a barrier when mapping the manipulation of the device onto the movements in the virtual world on the screen. Therefore, there is a necessity for an interactive display medium for games with playful physical interactions that foster direct haptic feedback.

TEI 2012, Kingston, Ontario, Canada, February 19 – 22, 2012.
© 2012 ACM 978-1-4503-1174-8/12/0002 $10.00

In order to reduce the discrepancy when exerting physical input on the interactive device, we utilized an everyday material that affords habitual actions. As shown in Figure 1, physical interactions are inherent features in both an inflatable object and a roly-poly. The tactile properties of the inflated object naturally drive various types of physical actions that deform the shape, such as punching, hugging and squeezing. The tension of the air density provides passive haptic feedback that presents sensual experiences. Additionally, the heavy and curved bottom part of a roly-poly toy transfers exerted input into kinetic reaction that fosters ludic experience.

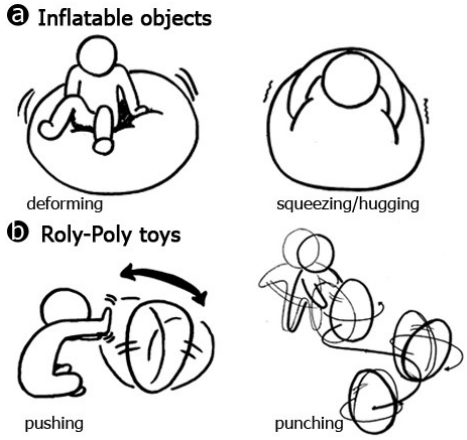

Figure 1. General interactions that are carried out with (a) inflatable objects and (b) roly-poly toys.

In this paper, we propose Inflated Roly-Poly, a medium that employs an inflatable object as a flexible display surface and borrows the mechanism of roly-poly toys as a means of spontaneous kinesthetic performance. We first review the similar approaches in physical interaction media and analyze the interaction techniques to present our work in a distinguishable manner. The properties of the chosen design materials are integrated with digital contents for implementation. With the prototype, we develop enjoyable game scenarios that induce unique interaction techniques. We then introduce the applications at a one-hour experience workshop involving four participants to see how they respond to Inflated Roly-Poly when it is utilized as a tangible entertainment media. Their engagements in games imply that exertion interaction enabled by inflated display with physical motion overcomes the barrier between traditional screen based games and intuitive user interactions.

RELATED WORK

Deformable Display

Designing directly deformable surfaces has been explored in various approaches in the realm of organic user interface [1]. Advancements in projector technology and touch sensing software encouraged designers to apply displays to objects and not be confined to rigid LCD screens. Khronos Projector [2] expressed that the tissue-based flexible screen efficiently assists direct manipulation. Once the material of the screen becomes flexible, its form factor can also be varied as an inflatable object. Multi-Touch Sphere [3] is a huge inflatable sphere built with a 360-degree projection and fish-eye camera mounted inside. Touch related applications like painting and drawing on the inflatable screen offers artistic expressions with tactile feedback. The form factor of the screen is more dynamically adjustable in Inflatable Multi-Touch Display [4]. It deforms its surface curve to convex or concave shape by inflation and deflation in accordance with the displayed contents and the context of the user task. Existing works demonstrate benefits of coupling input and output together through multi-touch interaction to create an organic user interface with a deformable display. We took the similar implementation method for our flexible multi-touch surface. However, the existing systems only allow interactions with the content in the immobile display surfaces, so that physically exerted input is limited to hand gestures. We present an interactive prototype with a deformable display which additionally entices active full-body movements. Inflated Roly-Poly enables playful kinesthetic interactions by allowing more freedom in dynamic motions. Compared to screen-based applications, it is better suited for physical entertainment scenarios.

Exertion and Spatial Interaction

Exertion interaction is poorly facilitated in screen based games due to safety and implementation issues. Mueller et al. [8, 9] have been contributed on exertion interaction in leveraging the benefits of physical exercise and sports games in HCI. Microsoft Kinect and Nintendo Wii are existing attempts to apply full-body movement and exertion interaction in real space for various game applications. However, these two systems lack haptic feedback and the involvement level is lowered. The user swings the arm in the air in order to compete with his competitor in the screen but only the virtual feedback is given. Our prototype overcomes this weakness with inflated display coupled with a movable roly-poly structure, as the user's bodily movements in real space drive haptic feedback. Tilting table [5] is a movable screen which allows user interaction to influence both the virtual content and the physical orientation. However the user's physical interaction is limited to tilting only. Inflated Roly-Poly, on the other hand, has more degrees of freedom in movement such as rotation and slide, in order to enable richer interaction scenarios.

DESIGN

Our goal in building Inflated Roly-Poly is to create an enjoyable experience with friendly materials and a playful form factor design, which builds upon the umbrella concept of 'embedded interaction'. We considered two main features in designing the prototype: the shape of the medium and the interaction techniques. By combining an organic shaped inflated body with a heavy, round bottom that makes the device inherently instable, we assume that it would effectively entice physical interaction.

The inflated body's surface needs to be implemented as a touch sensitive display in order to support intuitive manipulation with tactile feedback. When digital content is integrated with the tangible inflated body, it should provide a cue for deformability under intense force. This is rather new to traditional computer interfaces. Since deformation is caused by pressure, we use an air pressure sensor to detect when and how much force has been applied by the user.

When exertion inputs are applied to the device, the user expects to be provided with both visual and kinetic reaction. We maximized the benefit of a roly-poly's mechanism. It is a self-stabilizing device with tilt and rotation. This physical property of Inflated Roly-Poly invites the user to actively play with the prototype by moving around it or by displacing it. We anticipate that the user would appreciate the benefit of the integration of haptic, visual and kinesthetic feedback following an exertion input.

IMPLEMENTATION

Hardware

The basic configuration of the prototype is a white PVC inflatable balloon tube mounted on a heavy hemispheric bottom, as illustrated in Figure 2 (a).

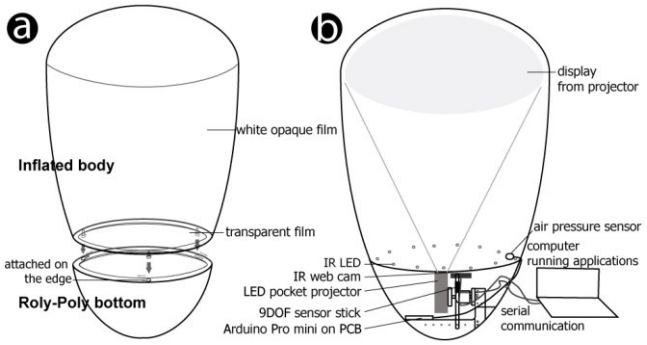

Figure 2. (a) External structure and (b) internal structure and components.

Size

The height and size of the prototype need to be such that people can easily reach it with their arms stretched during a game experience. Thus, the total height of the prototype measures 1065mm and the diameter of the top surface measures 430mm.

Input

Inflated Roly-Poly uses a flexible multi-touch surface, which comprises of an IR web-cam and a projector underneath the inflated body (Figure 2 (b)). An air pressure sensor (MPXH6115A6T1CT, 15 to 115kPa) is embedded inside of the inflated body to detect any deformation caused by pressure input. This has proven to be superior to the use of a movement-tracking web-cam, since pressure is exerted not only from the top surface, in the view of the camera, but also from anywhere else of the inflated body. A 9 DOF sensor stick (SEN-10724) is used to detect the movement of the hemispherical bottom of the prototype. The sensor stick detects tilting, rotating angle and direction of the prototype, and sends pitch, roll and yaw data to the CPU.

Output

The inflated body has transparent film on the bottom to enable clear vision of the web-cam and to project the digital image directly on the white, opaque surface on top and on the sides of the body, from the inside. The LED pocket projector (Vivitek, Qumi) is utilized to deliver a clear visual feedback with brightness level up to 300 lumens. It is connected to a separate power supply (AC 100-240V, 50/60Hz). Arduino Pro Mini (Atmega328/3.3V) facilitates serial communication between the sensors and computer (Intel® Core™2 Quad CPU Q9400 @ 2.66GHz, 4.00GM (RAM)) via USB connection.

Software

In order to integrate the data from all the sensors and to produce an interactive visual feedback, we used Processing, an open-source programming language which specializes in visual design projects. We used reacTIVision [7], an open-source tracking library, to detect the touch location of fingers. The library is very helpful as it provides an easy calibration method for non-planar surfaces.

INTERACTION

We developed a number of physical interaction techniques that employ full-body interaction. Gestures are categorized according to the body parts that perform the interaction.

Body

When we meet our beloved characters displayed on the inflated body, we may hug it. This hugging interaction was uncomfortable in standard rigid surfaces. Inflated Roly-Poly is made up of a volumetric air tube, and its softness encourages us to use the whole body, including arms and legs for interaction. We may tilt and rotate the display when navigate through 3D space or 2D maps. In game-related applications our prototype may act like a joystick. Moreover, it gives more freedom in manipulation technique than a standard joystick which does not support axial rotation.

Fist

Punching is a useful gesture in real-world physical games or sports, and provides fun and engaging experiences. In a conventional setting, it is a very unusual type of physical input as we cannot apply directly on typical rigid display surfaces. Inflated Roly-Poly reacts on punch with both passive haptic feedback and kinetic motion. The intensity of the applied punch brings various physical reactions, from swinging to shifting.

Hand

One of the attractive and distinguishing interaction techniques of the Inflated Roly-Poly is deformability. We can directly deform the volumetric shape by exerting pressure. We can squeeze the inflated display by one or both hands when modeling a virtual 3D object or distorting an image and the perception of tactile feedback allows a more intuitive, self-instructive interaction. Tapping or pushing is another type of interaction generated by a hand that can be utilized on our prototype.

Finger tips

We generally use finger tips in tasks that require subtle, continuous manipulation. For example, a slider allows a more detailed and intuitive control over speaker volume compared to up/down buttons. Due to its flexibility, Inflated Roly-Poly induces poking or pinching gestures, which, with haptic feedback helps intuitive, delicate manipulation.

APPLICATION SCENARIOS

We propose game scenarios that differentiate Inflated Roly-Poly from other interactive media. We aim to present applications that exploit the suggested interactions discussed in the previous section.

Squash Game

A ball is bouncing off from every side of the virtual walls in 3D room. When it bounces up to the display, the user smashes the ball to the other wall so that it bounces to another direction (Figure 3). Its tangibility provides a rich haptic feedback as the user actually smashes the display to hit the ball. Firmness of the balloon transfers the amount of required power when hitting the ball into passive haptic feedback.

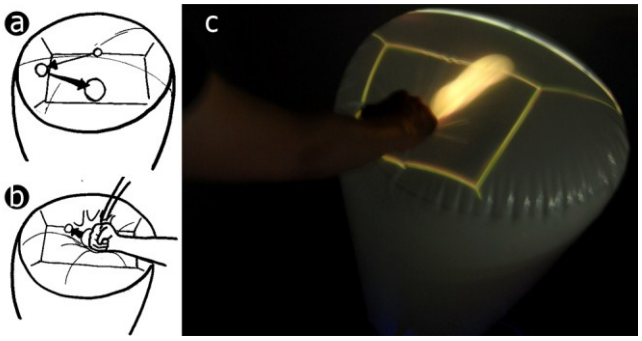

Figure 3. Punching the squash ball reflects it to the opposite direction.

Whack an Inflated Mole

'Whack a mole' is one of the all-time classic arcade games. When it is played with a keyboard or mouse, or even with a touch screen, lack of exertion interaction weakens engagement. We demonstrated a game named *Whack an Inflated Mole* (Figure 4). Red moles randomly appear on the background and the user whacks the moles to make them disappear (Figure 4 (a)). A Calibrated IR camera detects the punch spot on the screen. The user needs to tilt the device in order to navigate through the spherical virtual space (Figure 4 (b)). When the user strongly smashes the inflated body, every hidden mole comes out of the hole at once. During the immediate aftermath the device sways randomly (Figure 4 (c)) and the user can check how many and where about the moles remain on the virtual sphere.

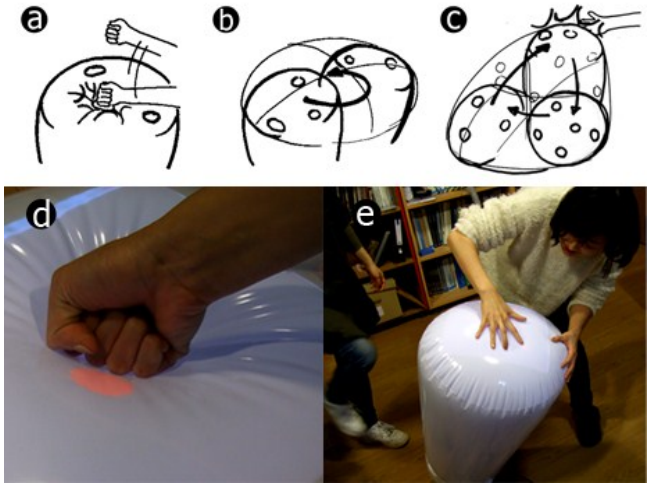

Figure 4. (a) Whacking, (b) navigating and (c) smashing. (d) The user whacks a mole. (e) The user tilts the device to navigate.

USER FEEDBACK

We had an experience workshop with four graduate students majoring in industrial design. When people first encountered Inflated Roly-Poly, they approached it with a gentle press or a push gesture and waited to see how it reacts. Before long, they easily grasped the idea of interaction. For the squash game, people replied that the tactile feedback they felt when hitting the display made them more engaged in the game. The game Whack an Inflated Mole successfully enticed full-body interaction. People responded that whacking on the target helped them to relieve stress. In order to navigate through the virtual space, people had to actively move their body, and this physical interaction made them feel as if they were playing a real-world game.

CONCLUSION

Inflated Roly-Poly was initially intended to introduce physical exertion as an interaction technique to an enjoyable entertainment medium that embeds digital contents. We developed a prototype to embody two features: passive haptic feedback from the inflated surface and spatial interaction with the form factor. With suggested interaction techniques that utilize full-body movement, we tried to explore the correspondence between the interaction techniques and contents (e.g. punching and tapping gestures agree with squash game). Through experience workshop and comments, we have examined the possibility of Inflated Roly-Poly as a playful, full-body interactive medium. We are envisioning that Inflated Roly-Poly will be commercialized and become a delightful everyday object incorporating exertion interface.

FUTURE WORK

In the current prototype, the kinetic motion is generated by exerted physical effort. We wish to improve Inflated Roly-Poly to embed actuated kinetic motion as a means of output. We may change the center of mass for spontaneous movements. Moreover, we hope to use a latex rubber balloon for the inflated surface, which may give a better tactile feedback when deforming the surface. Finally, we can generalize the prototype into two modules: the inflated body and the hemispherical bottom. Various combinations are possible with diverse shapes and sizes of the inflated body. Accordingly, it can easily be commercialized as an everyday object or a children's toy in the near future.

REFERENCES

1. Holman, D. and Vertegaal, R. Organic user interfaces: designing computers in any way, shape, or form. *Commun 2008.* ACM Press (2008) 51, 6, 48-55.
2. Cassinelli, A. and Ishikawa, M. Khronos projector. In *ACM SIGGRAPH Emerging technologies 2005*, Donna Cox (Ed.). ACM Press (2005), New York, NY, USA, Article 10.
3. Grant, E. Multi Touch Sphere. *TEDActive 2010*. http://vimeo.com/9386550.
4. Stevenson,A., Perez, C. and Vertegaal, R. An inflatable hemispherical multi-touch display. In *Proc. TEI 2011*. ACM Press (2011), New York, NY, USA, 289-292.
5. Lee, H.J., Khandelwal, M. and Mazalek, A. Tilting table: a movable screen. In *Proc. TEI 2007*. ACM Press (2007), New York, NY, USA, 93-96.
6. Lepinski, J. and Vertegaal, R. Cloth displays: interacting with drapable textile screens. In *Proc. TEI 2011*. ACM Press (2011), New York, NY, USA, 285-288.
7. Kaltenbrunner, M. and Bencina, R. reacTIVision: a computer-vision framework for table-based tangible interaction. In *Proc TEI 2007*. ACM Press (2007), New York, NY, USA, 69-74.
8. Mueller, F., Agamanolis, S., Gibbs, M.R. and Vetere, F. Remote impact: shadowboxing over a distance. In *Proc. CHI EA 2009*. ACM Press (2009), New York, NY, USA, 3531-3532.
9. Mueller, F., Agamanolis, S., Vetere, F. and Gibbs, M.R. A framework for exertion interactions over a distance. In *Proc SIGGRAPH Sandbox 2009*. ACM Press (2009), New York, NY, USA, 143-150.