SomaticBall: Ball-Type Device Providing “Sticking Feeling”

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Abstract
Many research projects on augmented sports have been proposed, which aim to extend sport experiences using computer technologies. We focus on interaction with balls, which are used in various sports. In this paper, we propose a ball-type device, "SomaticBall" which can provide a sensation as though the ball were stuck to the body.

Author Keywords
Augmented Sports; Interaction; Ball; Magnetic Force.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interface.

Introduction
Recently, many research projects on the augmented human have been proposed, which aim to extend human abilities using sensors, actuators, and computers. In particular, research projects on augmented sports have come to attract much attention. While traditional sport science focuses mainly on analysis of sports, augmented sports attempts to extend sport experiences using computer technologies.

In this paper, we focus on balls used in various sports and attempt to extend interactions between human bodies and balls. We propose a ball-type device, "SomaticBall" which

Figure 1: Basic concept of the SomaticBall providing "sticking feeling": The user can treat a ball as though it were stuck to his body.

can provide a "sticking feeling"; that is, a user can treat a ball as though it were stuck to his body (Figure 1). The "sticking feeling" is used as a metaphorical expression for the style of great players who handle balls with complete control. The SomaticBall aims to create such a sensation by controlling ball movements using magnetic force.

Related Work

In this section, we introduce related work in three categories: augmented sports, augmented ball, and interaction techniques using magnetic force.

Augmented Sports

Recently, many research projects on augmented sports have been proposed. Augmented DodgeBall [1] extended traditional dodgeball using computer technologies. In this system, each player has different "hit points" based on his or her physical abilities; then, the system attempts to fill the gaps between various players. PingPongPlus [2] extended the experience of playing ping-pong by creating computer graphics based on the ball movements and projecting them onto a ping-pong table. Designable Sports Field [3] is a virtual sport system that uses a large screen and aims to provide moderate exercise based on physical abilities.

Augmented Ball

Some research projects have focused on controlling and/or detecting ball movements for augmented sports. Bouncing Star [4] equips the ball with full-color LEDs and an acceleration sensor; the ball changes color according to its movements. HoverBall [5] is a ball-type device that has a small quadcopter inside a skeleton frame. A user can control the ball's movements using simple gestures; however, the user cannot directly handle the HoverBall (e.g., catching or throwing it) since the frame is quite fragile. TAMA [6] is another ball-type device, one that equips the ball with a compressed air tank inside. A user can easily throw breaking balls using TAMA; however, the user cannot use the ball continuously since a single throw empties the air tank.

Interaction Techniques Using Magnetic Force

There have been some research projects on interaction techniques using magnetic force, which is the type of technique focused on in this paper. ZeroN [7] is a tangible interface that can control a small ball in the air using electromagnet arrays. FluxPaper [8] can move sticky notes on a wall using electromagnet arrays. Our system is different in that it focuses on sport experiences.

SomaticBall

The basic concepts of the SomaticBall are as follows:

(1) Providing of "sticking feeling" in controlling the ball's movements.
(2) A wearable device that does not disturb body movements.

First, the SomaticBall aims to provide a "sticking feeling"–as though the ball were sticking to the body–in the control of the movements of the ball. We aim to achieve this goal by generating attractive/repulsive forces using electromagnets and controlling the relative positions of the ball from the body. Second, we designed the SomaticBall as a wearable device that can be used in various sports. We considered various shapes, such as a supporter, a shoe, and a glove; we selected a glove-type device for an initial prototype.

Next, we considered methods for controlling the ball's movements, such as wind force and magnetic force. We selected magnetic force for its ability to generate attractive/repulsive forces on the ball alone by attaching ferromagnetic material to the ball.

System Architecture

The SomaticBall consists of a ball-type device with ferromagnetic materials and a wearable device to generate the magnetic force (Figure 2). The wearable device is equipped with electromagnets to control the ball's movements using magnetic force. For example, when someone throws the ball to a user, the system helps the user to catch the ball easily by generating a gradual attractive force. In this study, we aimed to provide "sticking feeling" using magnetic force and to develop prototype systems to ascertain the proper ball structure and electromagnet configuration.

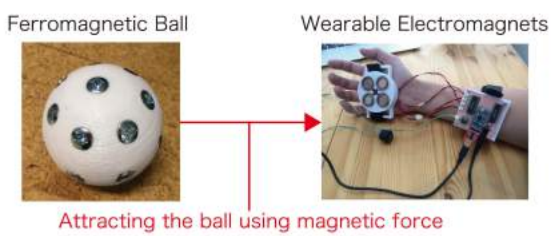

Figure 2: System architecture of the SomaticBall.

Implementation

In this section, we explain the SomaticBall prototypes in terms of the ball-type devices and wearable devices.

Ball-Type Devices

We developed four ball-type devices with ferromagnetic materials (Figure 3). These prototypes were designed by 3D CAD and created with a 3D printer. Prototypes 1, 2, and 3 were integrations of ferromagnetic materials and 3D-printed balls made with flexible filaments. Prototype 1 (magnet ball) was equipped with permanent magnets (diameter: 4.5 mm, magnetic force: 0.43 kgf) on the surface. Prototype 2 (screw ball) was equipped with stainless steel screws (M3 $\times$ 10 mm) embedded on the surface. Prototype 3 (iron-sand ball) included iron sand inside a ball-type case. Prototype 4 (magnetic-filament ball) was made entirely with magnetic filament. The diameter of each ball was 72 mm (nearly the same as a baseball). The weights of the balls were as follows: magnet ball, 220 g; screw ball, 160 g; iron-sand ball, 308 g; magnetic-filament ball, 80 g.[1]

Wearable Device

The wearable device consisted of a control element with a microcomputer and an actuator element with electromagnets (Figure 4). As mentioned above, it is a glove-type device designed to be worn on a hand.

The control element had a microcomputer, two motor drivers (NJM2670D2), and an acceleration sensor (KXR94-2050) on the original circuit board (60 mm $\times$ 60 mm). We selected the Arduino Pro Mini as a microcomputer to detect hand motion using the acceleration sensor and to control the electromagnets via the motor drivers; this microcomputer also supports serial communication with a PC for test and debug purposes. The circuit board had four connectors

[1] The weight of a baseball is about 143 g.

(1) Magnet ball.

(2) Screw ball.

(3) Iron-sand ball.

(4) Magnetic-filament ball.

Figure 3: Prototypes of ball-type devices.

to the actuator element and a connector to a trigger switch. These devices were installed in an original housing made by a 3D printer and could be fixed on a wrist with a strap.

The actuator element consisted of four electromagnets and an original housing. We applied TMN-2613S (diameter: 26 $\times$ 15, magnetic force: 60–175 N) as electromagnets. We developed three types of housing to ascertain the proper allocation of the electromagnets: a flat type (Figure 4), a finger type (Figure 5(1)), and a hemisphere type (Figure 5(2)). The flat-type housing distributes the electromagnets on the palm as 2 $\times$ 2 arrays, the finger-type housing positions each electromagnet on the fingers and palm, and the hemisphere-type housing sets the electromagnets inside the hemisphere placed on the palm. Each electromagnet

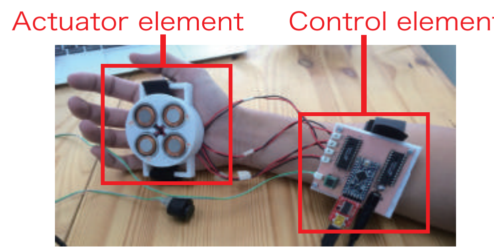

Figure 4: Overview of the wearable devices.

was controlled by the microcomputer through the motor drivers. In the current prototype, a user can control the state of each electromagnet using a trigger switch and/or serial communication from a host computer. As power supplies, we used 3.3 V for the control element and 15 V for the actuator element.

(1) Finger device.

(2) Hemisphere device.

Figure 5: Variations of electromagnet distribution.

Preliminary Evaluation

In this section, we describe the preliminary evaluation we performed to test the basic functions of the SomaticBall, that is, to ascertain whether our prototypes had enough power to attract still balls by magnetic force.

Evaluation Method
The details of the evaluation process are as follows:

(1) The experimenter places a ball on a table.
(2) He touches the ball softly from above using a device.
(3) He turns on the electromagnets and raises the device 15 cm.
(4) He observes whether the ball adheres stably to the device.
(5) He repeats Steps (1)–(4) for a total of 20 times.

We selected two balls (screw ball and magnetic-filament ball) and three wearable devices (flat device, finger device, and hemisphere device). These balls were selected in consideration of their proper weight and superior performance for being pulled by electromagnets. We also prepared a large stainless steel ball (shown in Figure 6) as a reference. The stainless steel ball consisted of two kitchen bowls (diameter: 15 cm, height: 6.5 cm), which were made with strong ferromagnetic materials (18-0 stainless steel). Each bowl had a flat part (diameter: 8 cm) on the bottom. We explored the attraction performance between the three balls and three devices.[2]

Results and Discussion
The evaluation results are shown in Table 1. The screw ball was attracted by the hemisphere device in 55% of the trials. We think the limited surface area of the screws affected this result; that is, the electromagnets often touched the plastic surface and failed to attract the ball. The magnetic-filament ball could not be attracted by any of the devices. Possible reasons are (1) the lower magnetic attraction of the material and (2) the thin surface (3 mm) and sparse density of the ball. The stainless steel ball (flat part) was attracted using the flat device in 100% of the trials. Moreover, the stainless steel ball (curved part) was attracted by the finger device in 85% of the trials. Possible reasons are (1) stable contact between the electromagnets and the ball and (2) strong magnetic attraction of the 18-0 stainless steel.

[2]We did not test the stainless steel ball with the hemisphere-type device because the device's shape did not fit the ball.

Figure 6: Stainless steel ball as a reference, made with two kitchen bowls.

From these results, we found that we need to consider the following points in designing the ball:

(1) Material: Attractive forces are quite different even among ferromagnetic materials. The evaluation results show that 18-0 stainless steel had the best performance.
(2) Surface area and shape: The stability of the contact between the electromagnets and the ball affects the attractive force. It is better to cover the whole surface with ferromagnetic material. In addition, the ball shape should be designed to match the device shape.

We plan to seek out further materials and design new balls that have the proper magnetic attraction, flexibility, and weight.

Table 1: Evaluation results.

Device ＼ Ball	Screw ball	Magnetic-filament ball	Stainless steel ball (flat part)	Stainless steel ball (curved part)
Flat device	0/20	0/20	20/20	0/20
Finger device	1/20	0/20	19/20	17/20
Hemisphere device	11/20	0/20	-	-

Conclusion and Future Work

In this paper, we have proposed a ball-type device, "SomaticBall" which can provide a "sticking feeling"; that is, the user can treat the ball as though it were stuck to his body. The SomaticBall consists of a ball-type device with ferromagnetic material and a wearable device to generate magnetic force. We developed four ball-type devices having ferromagnetic material and three wearable electromagnets controlled with a microcomputer. We also performed a preliminary evaluation to explore proper ball structure and electromagnet configuration.

In the future, we plan to seek out further materials and design new balls that have the proper magnetic attraction, flexibility, and weight. We will also explore further methods to more effectively generate attractive/repulsive forces.

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