Tabletop Interface using a Table's Circular Vibration and Controllable Friction

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Abstract
There have been many proposals for controlling moving objects with a tabletop interface. However it has been difficult to miniaturize or simplify the system. We propose a new simple tabletop system using the table's circular vibration and controllable friction of the moving object.

Keywords
Tabletop Interface, Tangible, Group Robots, Physical Interaction

ACM Classification Keywords
H.5.2.Information interfaces and presentation: User Interfaces.

Introduction
The tabletop interface is considered as a next generation GUI (graphical user interface). It is composed of a table type graphical display and physical objects on the display. It enables users to interact with the computer-generated world via physical objects, and hence, it is more intuitive than conventional GUIs. Recently, "active" tabletop interfaces have been proposed. Here, physical objects (referred to as "movers") have an actuator, so they can move and present tactile or haptic information to the user. The

system can also be thought of as a group robot interface.

Proposed active tabletop interfaces have a unique method to drive movers on the table. For instance, PICO[1] has arrays of electromagnets under the table. By controlling the electromagnets, PICO drives magnetic movers in an arbitrary direction. The Proactive Desk [2] is also composed of arrays of electromagnets under the table. It use the principle of a linear induction motor to import forces on the movers. In this case, a mover can be any conductive material, except iron. Although the proposed interfaces have succeeded in driving multiple moves independently, they need a large scale device to drive the movers from under the table. The other way to construct an active tabletop interface is by mounting an actuator on each mover. In other words, the mover becomes a micro-robot. However, in this case, it is difficult to miniaturize the mover. Current active tabletop interfaces have failed to convince that future systems can be small and simple.

Here we propose a new tabletop interface that can miniaturize the total system and movers at the same time. Our interface is novel in that it uses the table's circular horizontal vibration and controllable friction of the moving object. The speed and direction of the movers can be controlled independently, and the interface's speed is significantly faster than the previously proposed systems.

Related Works

In the field of robotics and automation, some devices have been proposed to drive objects on a table.

Reznik[3] proposed a system with four vibrators around a rigid plate. Force fields are generated on the plate by controlling the vibrators. Although it can drive individual movers independently, the speed is quite slow in principle, because the system uses a time-multiplexed control sequence. When the number of movers is N, the speed becomes 1/N. Vose[4] proposed a system with six linear actuators. The inclination field is generated on the plate by the actuators so that objects on the plate moves according to the generated "force vector field". The system aims to move numerous small parts on the plate. Although the principle is unique and interesting, it cannot control movers independently.

System Overview

Our system comprises a table and movers. (Figure 1) The table has a square shape (130mm $\times$ 130mm $\times$ 80mm), and has a speaker on each side. Square steel paper is connected to the speakers via a phosphor bronze spring. Using the mechanical resonance of the spring and steel paper, we can obtain sufficient amplitude (Figure 2) . The speakers are connected to an amplifier. Facing speakers are coupled and driven in an opposite direction with the same signal. Therefore, the connected steel paper vibrates horizontally.

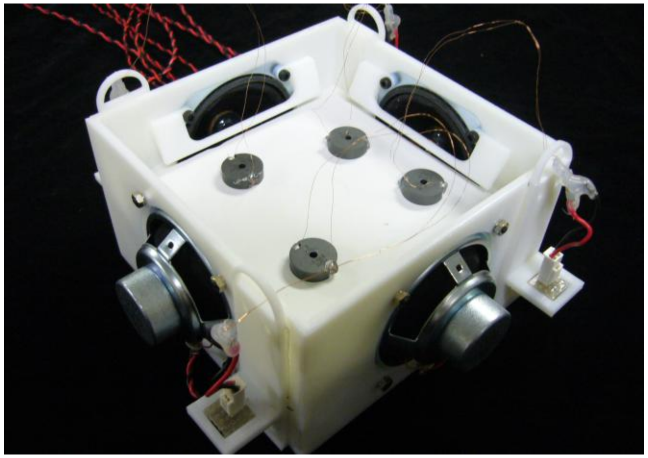

Figure 1. System overview.

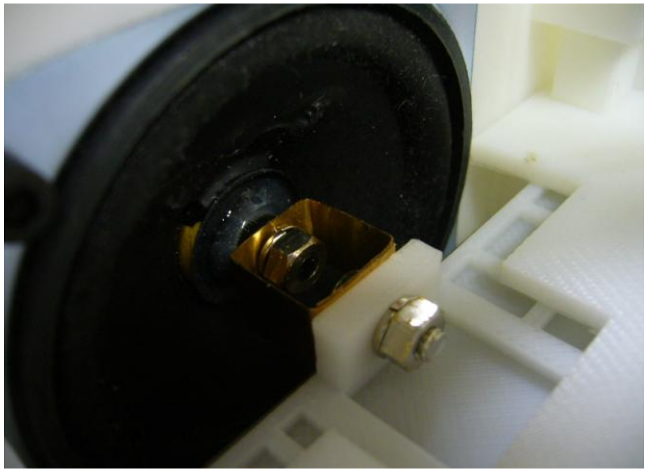

Figure 2. Joint made of phosphor bronze.

Figure 3. mover (left: mover, center: ferrite core, light: coil).

The mover is composed of an electromagnet (diameter: 15mm, height: 5mm). We used ferrite core so that a closed magnetic field is generated between the core and steel plate without an air-gap (Figure 3).

A microprocessor (Renesas, H8-3048) controls the table and movers by sending ON/OFF signals to the electromagnet of the movers and a sinusoidal wave to the speakers via an audio amplifier (Rasteme Systems, RSDA202, 20W) (Figure 4).

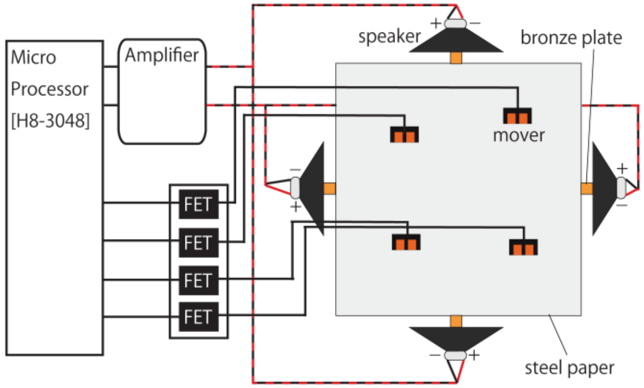

Figure 4. System figure.

Principle

1DOF motion

First we show the principle of one-degree-of-freedom (1DOF) motion. Left and right coupled speakers are driven with a sinusoidal current. The steel paper vibrates horizontally. Synchronizing to this vibration, we send a rectangular ON/OFF current to the electromagnet of the mover. The procedure is as follows.

(1) When the electromagnet is turned on, the mover is attached to the plate.
(2) The speaker vibrates, and the mover that is attached to the plate is accelerated.
(3) The electromagnet is turned off when the acceleration becomes a maximum.
(4) The mover is then released from the plate and slips on the plate.

Figure 5 shows the mover moving to the right, and Figure 6 shows the relationship between the speakers' driving signal and the mover's ON/OFF signal.

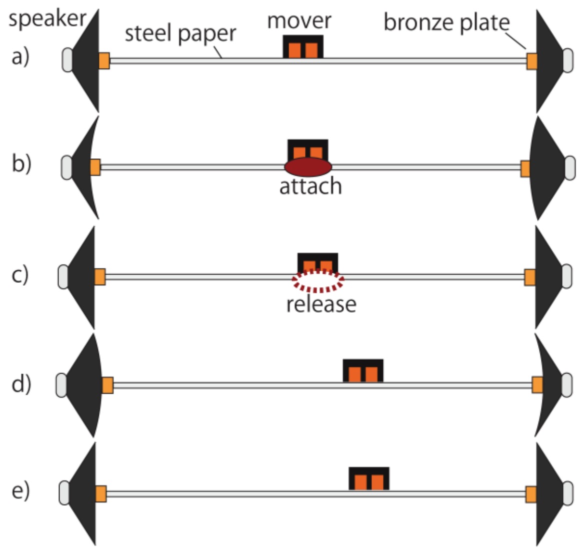

Figure 5. Principle of 1-DOF motion of the mover for the mover moving right.

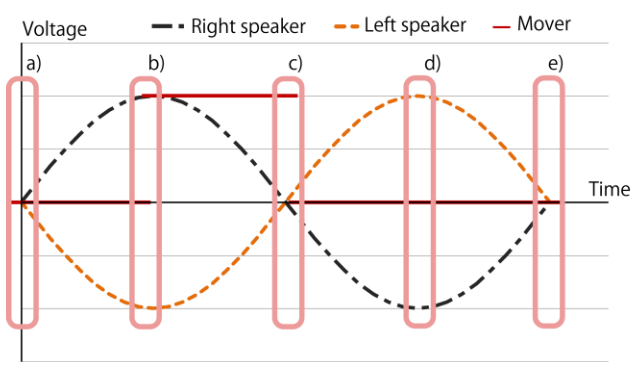

Figure 6. Relationship of the speaker voltage and electromagnet current.

2DOF motion

Next we show the principle of two-degrees-of-freedom (2DOF) motion. We send a sinusoidal current to the four speakers. Each current has a phase difference of 90º so the steel paper vibrates with a circular pathway. Just like the 1DOF case, the synchronized attach-release of the electromagnet moves the mover in an arbitrary direction (Figure 8). Figure 7 shows the relationship between the speakers' voltage and mover's attach-release signal.

Merit of the proposed principle

Compared to the previous systems, our proposed system has the following merits.

(1) Scalability: We can put any number of movers on the plate and can control them independently.

(2) Efficiency: the vibrating plate can be made very lightweight, so that it does not require much energy, especially when we utilize mechanical resonance. In addition, the electromagnet of the mover does not require much current, because of the closed magnetic field.

(3) High speed: As the mover is actuated by the actuator (speaker) outside of the mover, the system can achieve much higher speed compared to that of conventional micro-robot systems.

(4) Small size: The mover is composed of an electromagnet. Due to this simple structure, it can be made very small.

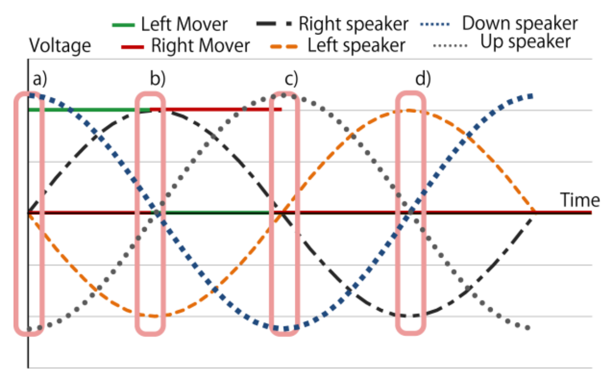

Figure 7. Relationship of speaker voltage and electromagnet current.

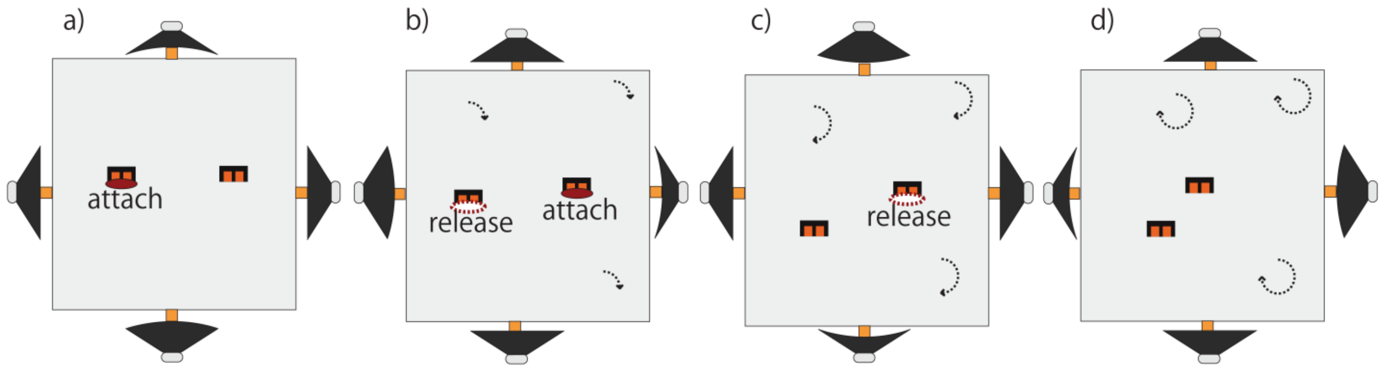

Figure 8. Principle of 2-DOF motion of the mover. The left mover moves down and right mover moves left.

Experiment

We have made and evaluated a prototype system. The mover's maximum speed was 115mm/s and we could control two movers independently (Figures 9 and 10).

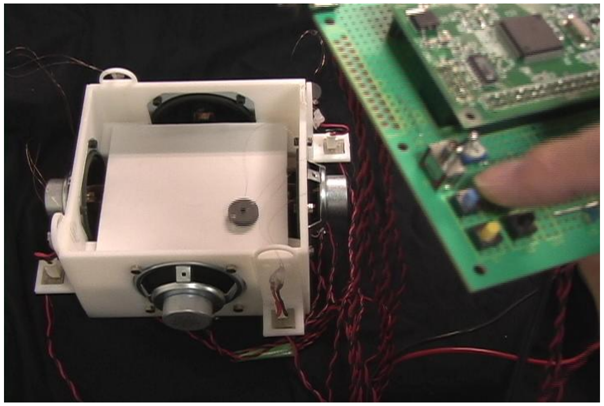

Figure 9. Controlling one mover.

Conclusion

In this paper we proposed a simple tabletop interface using horizontal vibration of the table and movers with electromagnets. We showed the principle of 1DOF and 2DOF motion.

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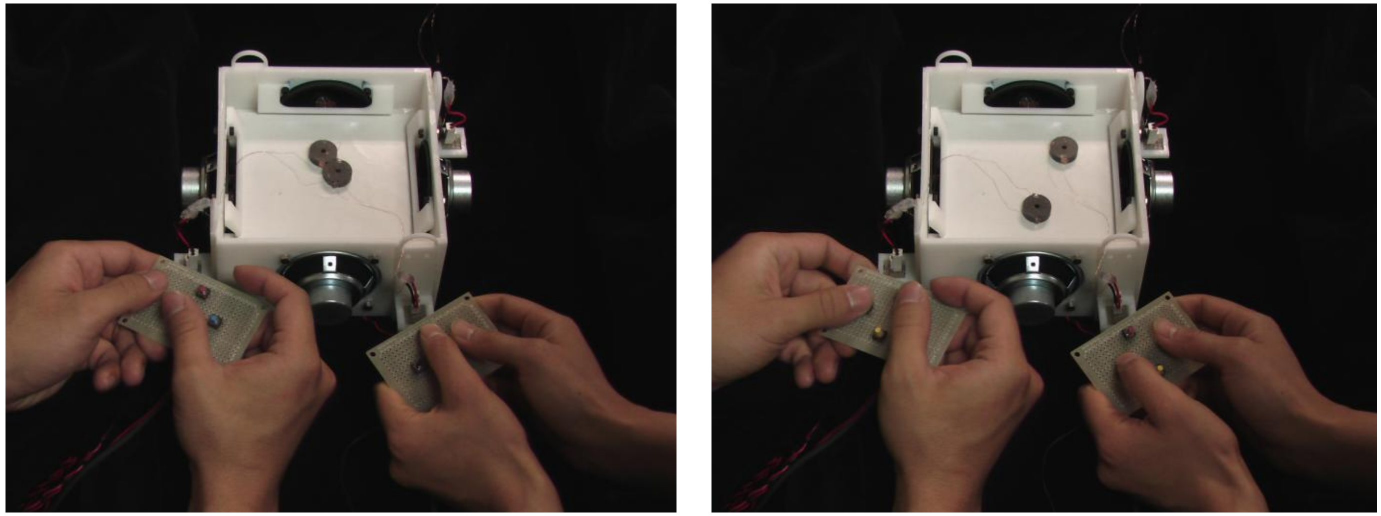

Figure 10. Controlling two movers independently.