Developing fMRI-Compatible Interaction Systems through Air Pressure

Handityo Aulia Putra
School of Information
Kochi University of
Technology, Japan
handityo.aulia@gmail.com

Xiangshi Ren
Center for Human-Engaged
Computing
Kochi University of
Technology, Japan
ren.xiangshi@kochi-tech.ac.jp

ABSTRACT
We leverage the use of air pressure to expand the interaction space within fMRI (functional magnetic resonance imaging). We present three example applications that are not previously possible in conventional fMRI interaction devices: 1) *pedal interface* that can record continuous pressure value pressed by users, 2) *wrist tactile interface* that can provide various tactile patterns or stimuli, 3) *adjustable resistance joystick* that can provide feedback through different resistance levels. Our work shows that the use of air pressure can enable new research opportunities for fMRI researchers.

Author Keywords
fMRI; response device; air pressure; tactile feedback.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
Functional magnetic resonance imaging (fMRI) [1] enables medical doctors and researchers to study correlations between brain activation and tasks performed by participants during a brain scan. In a task that requires more input choices or special stimulation rather than binary input or visual stimulation, additional equipment is required. For example, fMRI researchers may want to understand some driving behaviors and record analog input using pressure sensitive pedal interaction, and want to understand brain mappings of tactile sensations by providing some tactile stimulation to the participants.

However, there is a limited choice of interaction systems that allow recording analog value, providing tactile stimulation, or both. Air pressure system and 3D printer technology can be utilized to address this issue but has been under-explored for fMRI [4]. Although some fMRI-compatible air-based systems exist, they are limited to a single configuration to provide output only, such as robot interaction [3], skin stimulation [5], haptic interface [6].

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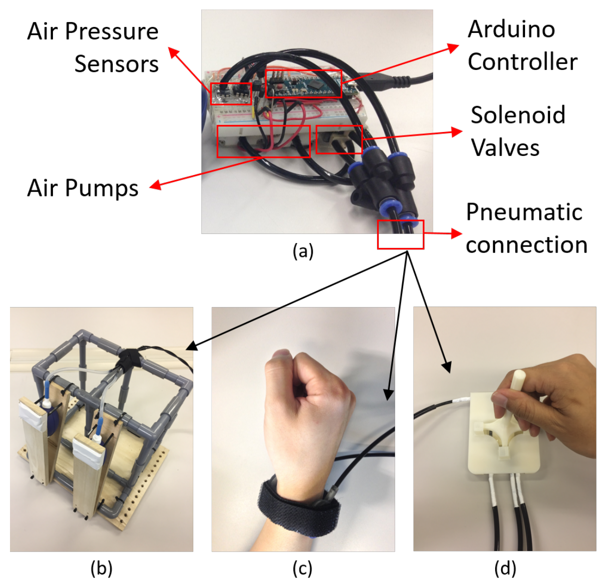

Figure 1: Air-based system components (a) and its three possible configurations: (b) analog pedal interface, (c) wrist tactile interface, (d) adjustable resistance joystick interface.

This paper proposes an fMRI-compatible air-based system, that can be configured to record analog input, provides tactile stimulation or both tasks (record input and provide tactile stimulation) to users in the fMRI environment. We showcase our air-based system in three configurations, i.e, pedal interface, wrist tactile interface, and adjustable resistance joystick, as shown in Figure 1. We envision that in the future air-based systems will allow fMRI researchers to expand their choice of tools in experiments aimed at understanding human behavior using fMRI scanners.

FMRI-COMPATIBLE INTERACTION DEVICE
Figure 2 shows electronic and pneumatic configurations of the air-based system. The main consideration for the system is that all components which will be put inside fMRI need to be non-ferromagnetic. The pneumatic-based systems that we

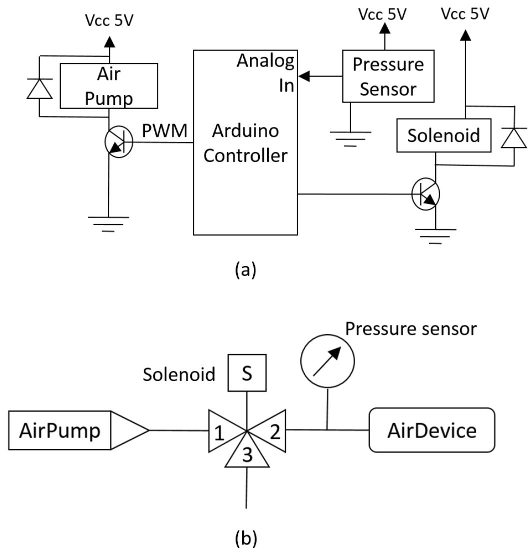

Figure 2: (a) Electronic diagram of the air-based system, (b) pneumatic configuration for analog input detection and tactile feedback generation.

explore in this work rely on changes in air pressure to record user response information and to generate tactile sensation to users inside the fMRI scanner.

APPLICATIONS

All configurations of the air-based system shown in Figure 1 have been evaluated for fMRI-compatibility on a 3.0 Tesla scanner. We confirmed that the air-based system conforms the requirements to be used inside the fMRI. We illustrate some potential applications of fMRI-compatible air-based interaction system in the following subsections.

Pedal Interface

Figure 1b shows a pedal interface which has the ability to measure variable pressure strength applied by the user for acceleration and brake, unlike conventional fiber-optic pedal interface which can only detect binary information (pressed or not). Variable pressure strength recording can be used to investigate whether the users did a mid-way error correction. For example, a driver pressed acceleration on a red light and realized half-way that he/she should have pressed brake, then the driver stopped pressing acceleration pedal and changed to press the brake pedal. This error correction cannot be detected by an on-off only interface.

With the mid-way pressure information available, fMRI researchers can possibly study which part of the brain is responsible for decision making and decision correction. The pedal configuration has been and currently utilized to study driving behavior of different age group people by fMRI researchers in our university. The study shows that the pedal can provide analog pressure information without reducing the quality of fMRI scanned images.

Wrist Tactile Interface

Figure 1c shows the air-based system in a wrist tactile configuration, which consists of multiple 3D printed flexible buttons that can be inflated and deflated depending on its internal air pressure. This can be used to simulate a vibration or squeezing sensation with many different patterns to the user's wrist by manipulating the internal air pressure level of the system.

This wearable wrist configuration can be leveraged to study the effectiveness of HaptiColor [2] from a brain study perspective. The fMRI researchers can further investigate whether there is an association between color and spatiotemporal tactile sensation.

Adjustable Resistance Joystick Interface

Figure 1d shows an adjustable resistance joystick interface that can provide x-y coordinate input with simulated resistance. The strength of resistance can be controlled by manipulating internal air pressure for each air-pocket, i.e., resistance is higher with higher internal air pressure.

The joystick is 3D-printed and consisted of four pressure sensitive air-pockets. The adjustable resistance characteristic allows fMRI researchers to manipulate different resistance for joystick interaction and study whether different resistances have an impact on human motor skills.

FUTURE WORK

We are currently designing the configuration for fragrance delivery inside fMRI, where we will conduct an fMRI study regarding the effect of specific fragrance to the human brain. We envision that fMRI researchers can do different tasks (recording input, providing feedback, delivering fragrance) by utilizing one system only (with multiple configurations).

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