

Sync Sofa: Sofa-type Multimodal Communication System that Provides a Feeling of Being Next to Each Other

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ABSTRACT

We have developed a new communication system: "Sync Sofa" based on the concept that a user can communicate with their partner as if he or she is next to the user. Because Sync Sofa is equipped with visual, audio, and tactile input/output devices, it can transmit the sensation of the partner being next to the user via a network even if the partner is in a remote location.

1 Introduction

Due to the spread of Covid-19 and the increase in the number of single-person households, the opportunities for intimate contact and communication, such as touching an arm or shoulder, snuggling up and so on, are decreasing. The lack of such communication may have a negative impact on mental health, self-esteem, and the immune system [1][2][3][4]. One solution to this challenge is to make such intimate contact and communication available online.

We have developed a new communication system in the form of a sofa-type device in order to realize communication that allows people who are far away from each other to interact as if they were in the same space. The system has visual, auditory and tactile display devices that enable the presence of the partner to be conveyed through several modal expressions. These comprise natural motion parallax, sound localization highly linked to the partner's position, and the generation of multi vibrotactile sensations.

2 System

The 3D design of Sync Sofa is shown in Fig. 2. The technical elements of each of the visual, audio and tactile modalities are described below.

2.1 Visual

A 55-inch 4K monitor, placed next to where the user sits, shows a life-size image of the partner, in the form of a billboard model [5]. Motion parallax was implemented to enhance the sense that the partner was present. To generate the parallax effect, a depth sensor, Azure Kinect [6], was installed in front of the sofa to track the user's head position. The billboard-based object corresponding to the partner is placed with background objects such as sofa and room in a virtual 3D space, and then this system renders the virtual camera view synchronized with the

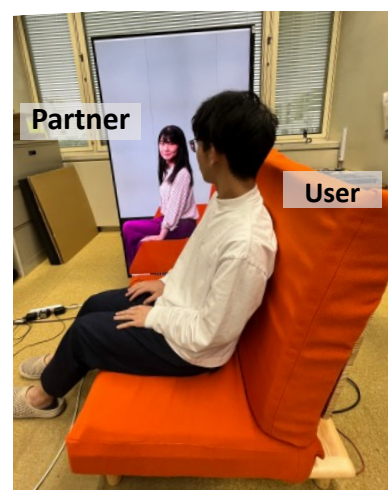


Fig. 1: The sideview of Sync Sofa

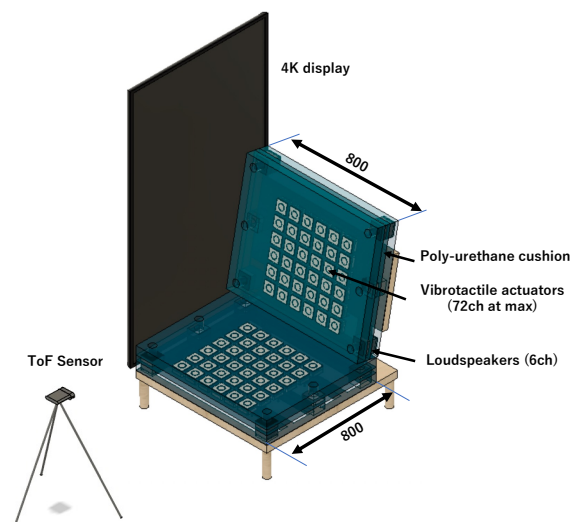


Fig. 2: The 3D design of Sync Sofa

tracked user's head position. The motion parallax effect achieved in this way allows the user to approach or look around the partner on the monitor without discomfort.

2.2 Audio

To balance the wide sound image localization and the simplicity of the system, six full-range loudspeakers are installed, four on either side of the back and two on either side of the seat. They are placed at a sufficient distance from each other so that the sound image can be widely

localized by controlling the intensity of each loudspeaker or filtering the audio stream. In order to output motion sounds (the sounds of footsteps, rubbing, etc.) and speech sounds separately, different types of microphones are placed to capture motion sounds and speech sounds, respectively. The intensity of each loudspeaker and the filter for the directional band were parametrically and heuristically adjusted. The motion sounds were heard from the partner's sitting position and the speech sounds from the partner's face position. Finally, the user can hear the motion sounds and the speech sounds, the sound image localization of which is linked to the image on the monitor [7].

2.3 Tactile

Sync Sofa has the capacity for 72 vibrotactile actuators at the max installation. We installed eighteen vibrotactile actuators into the sofa at the total because of the limitation of the number that the driver can drive simultaneously, and twelve on the back and six on the seat. Voice coil actuators, Dayton Audio DAEX30HESF-4, are used as the tactile actuators and can be driven by an acoustic signal. In addition, unlike ordinary speakers, they can generate vibrations in a low frequency band with high efficiency, and its resonance frequency is around 130Hz. Each actuator is driven independently by an analog signal, the drive power of which is 15W at maximum. The positional arrangement of the actuators was designed taking into account the limitations on the number of actuators and the shape of the shoulders and buttocks of a typical Japanese person. The actuators are located under a poly-urethane cushion 50 mm thick, however, the user can feel the sufficient vibration.

The drive signal is a mixture of an acceleration signal and an audio signal, and each sensor is placed on the back and the seat of the sofa the partner is sitting on. By driving tactile vibrations from the acceleration signals, the user can experience all the movements the partner makes precisely because the accelerometer has high spatial resolution. However, if only acceleration signals are used, the vibration becomes largely disengaged from the audio content, e.g., the motion sound is very small, but the tactile vibration is very large. Hence, we decided to use audio signals, too, so that the signals are processed with frequency filtering to drive the actuators effectively and outputted to the actuators. This allows the user to feel tactile sensations that are highly linked not only to the partner's position and movement but also with the audio experience.

Finally, we set up the one-way communication system as shown in Fig. 3.

3 Workshops

We held workshops to evaluate our system. About 100 men/women aged from 20s to 60s took part in the workshops and experienced two types of content, live content and pre-recorded content. In the live content,

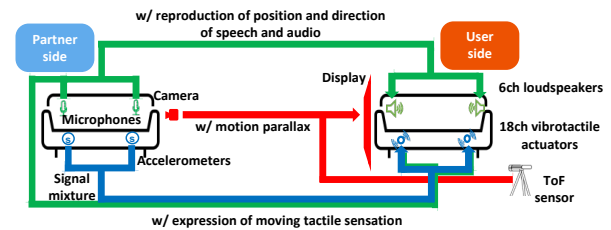


Fig. 3: The one-way communication system of Sync Sofa

using Sync Sofa, the participants communicated with their partners who were in a remote place. In the pre-recorded content, the participant experienced the specific scenario which is pre-recorded. We prepared four recorded scenarios for the workshops; these are described in the following and shown in Fig. 3. Each scenario has been created as content suitable for experiencing the functional features of Sync Sofa.

- (1) Scenario where the partner comes in and sits next to you.
- (2) Scenario where the partner rises from the sofa, sits down again and leans against the back.
- (3) Scenario where the partner comes about 20 cm closer to you on the sofa, strokes your back and then taps your back lightly.
- (4) Scenario where the partner is watching a soccer game on TV and cheers the moment a goal is scored.

We got feedback from the workshops participants on each of the scenarios outlined above.

3.1 Feedbacks

Both types of content were mostly well received by the participants. There was no one who said that they felt visually and auditorily uncomfortable, but on the other hand, about the half said that the tactile vibration was felt to be stronger or weaker than the partner's motion. This may be because the contact force between the actuator and the body differed depending on the participant because of differences in body size or the sitting posture.

During the experience, many participants said, "I feel very shy because I feel as if my partner is by my side" and it was suggested that Sync Sofa induces in users the same sense of shyness they feel in face-to-face communication. In addition, compared to the pre-recorded content, it was found that the participants tended to feel the presence of the partner and the shyness far more with the live content.

Some of the participants remarked that they had the sense that their partner was next to them. In particular, most participants also mentioned that the motion parallax effect contributed to this feeling of presence. It is assumed that the sense of the partner's position reproduced by the motion parallax contributed to the effect that the partner was next to them.

In addition, some of the participants mentioned that

the partner's speech sounded as if it was coming from the direction of the monitor on which the partner's image was displayed, moreover, this effect was felt even when the participant did not pay attention to the monitor image. This suggests that sound image localization effect was produced with sufficient realism.

In order to confirm the acceptability of Sync Sofa, we asked the participants if the sense of their partner being present made them feel uncomfortable, and they answered that they initially felt uncomfortable or out of place. However, it was found that many participants tended to adapt to the situation after a few minutes and began to feel as if their partner was present. This suggests that the experience generated by Sync Sofa is generally acceptable and the time required for adaptation is acceptably short.

4 Conclusions and future work

We proposed a new communication system, Sync Sofa, which makes it possible for the user to communicate with their partner as if he or she is next to them. Sync Sofa has a large monitor, 6-channel full-range speakers, and 18-channel tactile actuators. The Sync Sofa makes it possible for the user to feel the position or motion of their partner by means of the display and the various functions that Sync Sofa controls.

The findings of the workshop we held suggest that Sync Sofa can give the user the impression that their partner is next to them, and furthermore, also suggest that the experience generated by Sync Sofa is sufficiently acceptable for practical use.

In the future, we will perform demonstration experiments of bidirectional communication over the Internet. In addition, we plan to evaluate acceptability in more detail for general use.

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