# Jorro Beat: Shower Tactile Stimulation Device in the Bathroom

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## Abstract

We present a shower-type tactile device, named "Jorro Beat". It enriches the music experience in the bathroom by providing tactile stimulation synchronized with music to a wide area of the skin by controlling the water flow of the shower. Our prototype device consists of a showerhead with a mechanical switch, a microcontroller, a motor driver, a DC motor and a cam that is connected to mechanical switch on the showerhead. We conducted an experiment to evaluate the performance of the device, namely bandwidth, latency and operating volume, and showed that the device has sufficient capacity for an enriching music experience, with up to 2100 beats per minute and around 54 dBA operating volume.

## Author Keywords

Bathroom; Haptic; Music; Shower; Water;

## ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces—Haptic I/O

## Introduction
The bathroom is a place for cleaning our bodies, and also a place to relax. Wide spread use of waterproof audiovisual devices allow us to enjoy movies and music in the bathroom, and novel entertainment systems for the bathtub have been developed [5][6]. Conversely, entertainment systems for use while taking a shower have not been proposed so far.

We frequently have to close our eyes while taking a shower, which makes visual entertainment difficult. However, the shower provides a strong tactile sensation to the whole body, which leads to the idea of using the shower itself as an enriching music experience. Numerous studies to enrich audio visual content with tactile stimuli using jackets [1], chairs [2][3], and blankets [3] support our idea.

In this paper, we present a shower-type haptic device, named "Jorro Beat", which provides tactile stimuli synchronized to music. The device controls the water flow by means of a mechanical switch in the showerhead and the water flow pulsates on a wide area of the user's body (Figure 1). The contributions of this work are: 1) the implementation of a showerhead that can control water flow and beat out a rhythm; and 2) quantitative evaluation of the performance of the device. The paper first describes a literature review of digital entertainment systems in bathrooms and tactile feedback systems using water. Next, we describe the construction of the device. We then evaluate our prototype device including beats per minute (BPM) bandwidth, latency and operating volume. Finally, we describe possible use of the device and discuss the limitations of the present work and future research directions.


Figure 1 "Jorro Beat": water flow from the showerhead synchronizes music and beats out a rhythm on a wide area of the user's body.

## Related Work
In the research field of computer entertainment, various entertainment systems for use while in the bathtub have been developed. Hirai et al. developed the Bathcratch interface, which detects scratching hand motion on the edge of a bathtub and outputs sounds like a disk jockey [5]. Koike et al. developed the AquaTop display, in which visual widgets are projected on the surface of a white water solution and the motion of the user is measured to allow interaction with the widgets [6].

In addition to audio and visual interaction in the bathtub, haptic interaction has also been developed. Nakamura et al. used an electro-tactile stimulation technique to present tactile sensation to anywhere on the body under the water [7]. However, it is still in the early stage of development, and applying it to shower

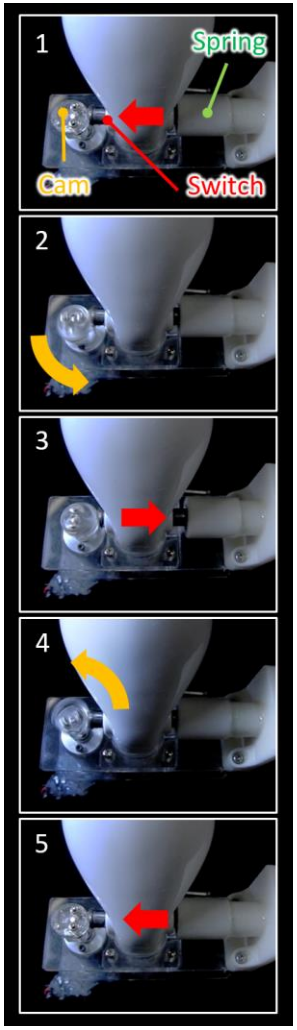


Figure 4 Cam mechanism

is quite difficult because of the unstable current pathway through the water flow.

Controlling water flow is a natural way of providing tactile stimulus in the shower. Richter et al. developed the LiquiTouch, in which a nozzle mounted on a robot arm emits a water jet to the touch of a fingertip [8]. Hoste et al. developed the Water Ball Z, which emits water jets to the user's body as tactile feedback of a fighting game [9]. These ideas employed the technique of controlling water flow as a method of tactile feedback, but at relatively low speed.

## Device configuration

To provide tactile stimulus while taking a shower, we control the water flow using a showerhead with a mechanical switch.

We created a prototype (Figure 2), consisting of a microcontroller (NXP Semiconductors, mbed NXP LPC1768), a motor driver (TOSHIBA, TA8429HQ), a showerhead (Task Three Co. Ltd., PTB2902), a DC motor with a rotary encoder (Maxon Inc., 10W, RE25), an acrylic oval cam and a stainless compression spring (wire diameter, 1 mm; outer diameter, 12 mm; length, 43 mm; maximum compression length, 12 mm; and maximum load, 1.7 kg). As shown in Figure 3, the showerhead can switch the water flow (open / closed) by pressing the mechanical switch by 8 mm.

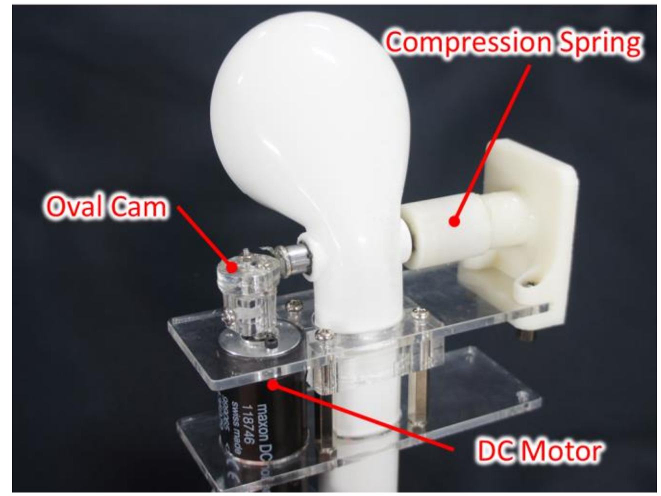


Figure 2 Prototype device: a mechanical switch on the showerhead is pushed by a camshaft.


Figure 3 Mechanical switch on the showerhead: pushing the switch by 8 mm can switch the water flow (open / closed)

As shown in Figure 4, the motor, the cam and the spring push the switch on the showerhead a distance of 8 mm. The rotation of the motor is controlled by a microcontroller employing a Proportional-Derivative controller with a 1-kHz refresh rate. The current prototype is normally open, i.e., water flows from the showerhead unless the switch is pushed.

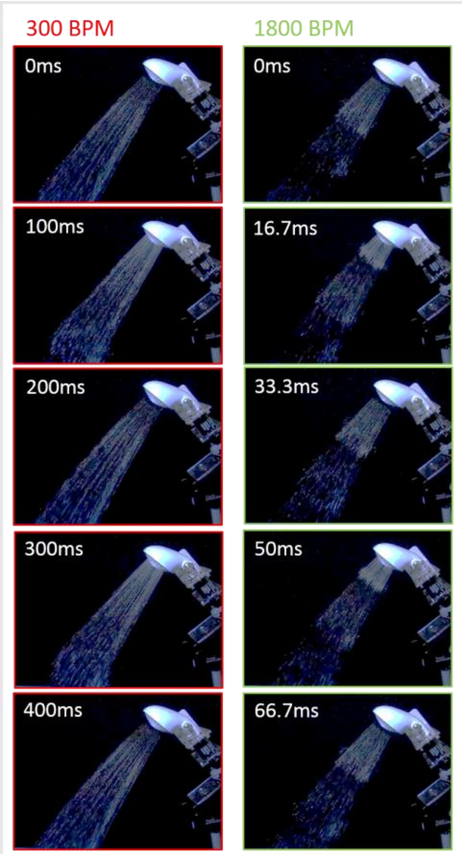


Figure 6 Water flow observed by high speed camera (300 BPM, 1800 BPM)

## Evaluation

We evaluated the performance of our prototype to see the reaction to music.

### *Bandwidth and Latency*

In this experiment, we studied how many BPM the prototype was able to provide. We also measured the velocity of the water flow to compensate for the latency in tactile sensation.

#### Experimental Setup

The setup of the experiment is shown in Figure 5. The prototype showerhead was connected to a water pump (Koshin Ltd., SM-525, maximum ejection volume 100 L/min) in a tub and fixed to a tripod stand. A scale was fixed on the showerhead pointing vertically downward. The tub was filled with water and collected the water discharged by the showerhead. The microcontroller drove the prototype to instantly alter the switch state at 60 to 3000 BPM. This was monitored using a high speed camera (CASIO, EXILIM EX-F1, 300fps).

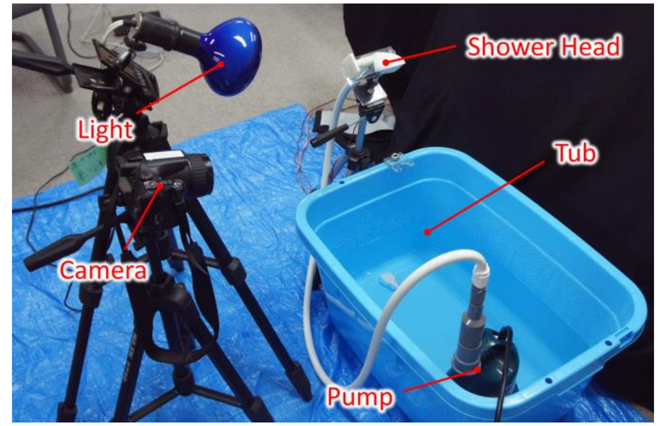


Figure 5 Setup to measure the bandwidth and latency

#### Result of Bandwidth

Using high speed video, we confirmed that up to 2100 BPM, the water flow can be clearly separated (Figure 6). At 2400 BPM, we observed that the water flow did not achieve the desired BPM. The recorded encoder value showed that the motor did not reach the desired angle at 2400 BPM, which can be improved by using a more powerful motor. However, the BPM of most genres of music, such as drum 'n' bass, is less than 300. The prototype has enough bandwidth to beat out a rhythm.

In our preliminary test, users could sense frequencies from 60 to 2100 BPM provided by the prototype and discriminate them from a normal continuously flowing shower.

#### Result of Latency

As show in Figure 7, we counted the number of frames required for water to travel 10 cm. The number of frames was around 7, resulting in a water flow of approximately 15.4 km/h (=10 cm/7 frames/300 fps).


Figure 8 Setup to measure the sound level of operating volume: The sound level meter was located 50 cm away from the showerhead.

If the user's skin was located 50 cm away from the showerhead, the latency was around 117 ms. According to previous literature [10], more than 40 ms asynchrony between audio and tactile sensations is detectable. Delaying music reproduction can solve this problem.

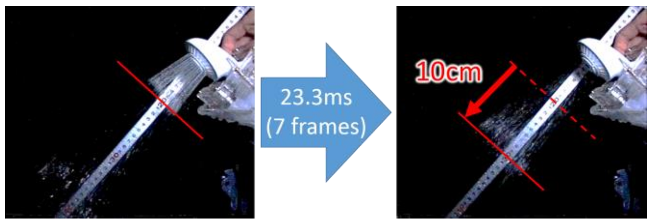


Figure 7 Speed measurement of water flow

*Operating Volume*

In the previous section, we concluded that the latency of tactile stimulation should be compensated by adding delay to the music. However, if the operating volume of the device was too loud, it would need another unnecessary sound cue to precede tactile stimulation. In this experiment, we measured the sound level of the operating volume.

### Setup

We conducted the measurement using a sound level meter (Tenmars Electronics Co., TM-102) in a quiet room (30.0 dBA).As shown in Figure 8, the prototype showerhead was fixed on a tripod stand and the sound level meter was set 50 cm away from the showerhead, which assumed the position of the body while taking a shower.

The microcontroller drove the prototype to instantly alter the switch state at 60, 120, 180, …, 1200 BPM without water flow. We measured the sound level for five seconds and recorded the maximum value. In addition, we measured the sound level of the shower with the showerhead open.

### Results

Figure 9 shows the sound level of the operating volume of the prototype and the shower. Regardless of the BPM, the sound levels of the operating volume were stable and the average was 53.8 dBA. The sound level of the shower was 63.9 dBA. Thus, the sound level of the operating volume was 10 dBA less than that of the shower.

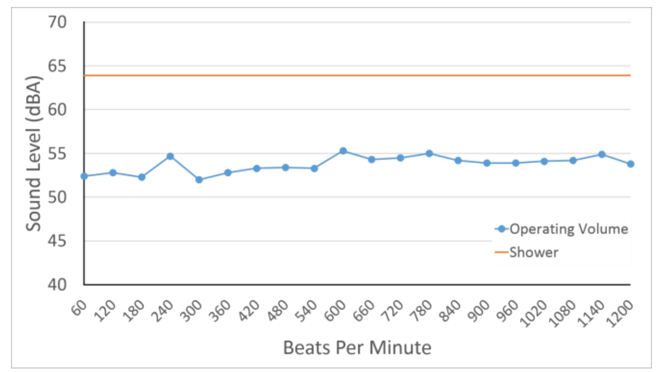


Figure 9 Sound level of operating volume for 60-1200 BPM. "Shower" is the background noise of the water from the shower.

In the preliminary user test, users reported that they did not hear the operating volume unless paying attention to it. In addition, playing music also masked the operating volume.

## Conclusions

In this paper, we present a shower-type tactile device that provides tactile stimuli synchronized to music to a wide area of the skin on a user's body and enriches the music experience in a bathroom. Our prototype device employed a spring-cam mechanism to control the water flow of the shower. The evaluation showed that the device can present up to 2100 BPM with a 54 dBA operating volume. Moreover, we found unacceptable latency in the tactile stimulus, which could be compensated for by setting a delay to the music.

The current prototype has several limitations. One is the limited bandwidth. 2100 BPM is equivalent to 35 Hz, but the tactile channel can accept up to 1 kHz. We will investigate improvements to the device, as well as the necessity to present a high frequency tactile signal.

We also plan to conduct a user study that will examine the experience when using the device. We are interested not only in passive experience, such as listening to and feeling music, but also in active experience, such as playing live music with an input interface. We will research the change in the passive and active experience when using the device.

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