Design of a tactile jacket with 64 actuators

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ABSTRACT
In this paper, we present a tactile jacket with 64 actuators. We briefly describe the design of the jacket and the system aspects.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User interfaces – *Haptic I/O*

General Terms
Experimentation, Human Factors

Keywords
Tactile stimulation, vibrotactile actuators, textile electronics

1. INTRODUCTION
At Philips Research, we investigate the possibilities of tactile stimulation because it offers an extra modality for user interaction. More specifically, we want to establish how this kind of stimulation can be optimally used in consumer products. In order to study tactile stimulation we have designed a comfortable jacket containing an array of tactile actuators. This jacket serves as a research vehicle for studies on the effect of adding tactile stimulation to existing or future products.

In the next section, we briefly describe the design and implementation of our jacket. In section 3 we describe how we generate the tactile stimuli. We end with conclusions and acknowledgements.

2. HARDWARE
2.1 The jacket
Our starting point for the jacket was a design that could stimulate the back and front of the human torso and arms. In this design we incorporated 64 actuators. Distributing these actuators uniformly over the jacket results in a layout with roughly 15 cm distance between neighboring actuators.

Further design constraints were a tight fit and good accessibility of the electronics. The tight fit makes sure that the actuators are as close as possible to the human skin. This requires the use of a stretchable fabric and different clothing sizes: small, medium, large, and extra large.

The jacket consists of two layers: an outer lining and an inner lining. The electronics were attached to the inner lining and then covered by the outer lining for protection and aesthetics. At the bottom side and at the end of the sleeves the linings were not sewn together such that the electronic components remained accessible for debugging and repairs (see Figure 1 upper panel).

Figure 1. Upper panel: photos of tactile jacket with outer lining (left) and inner lining containing electronics and wires (right). Lower panels: distribution of vibrotactile actuators on front (left) and back (right) of a torso. The actuators are represented by the colored circles and are grouped into 16 segments each containing four actuators.

2.2 Actuators

For the jacket we have chosen for pancake–shaped Eccentric Rotating Mass (ERM)-motors because they are light weight, thin, and cheap compared to other offerings. Their main electrical characteristics as well as some of their mechanical characteristics are listed in Table 1.

Table 1: Specifications of the vibration motor.

Characteristic	Specification
Operating voltage	2.5~3.5 V_{DC}
Max. Current	90 mA
Coil Resistance	80 Ω_{max}
Mass	0.08 gram
Rotation Speed @ 3 V_{DC}	13000 ± 2500 rpm

Because of the low operating voltage it is possible to drive the actuators using two AA-batteries in series. These batteries deliver typically about 2800 mAh which yields a operation lifetime of 1.5 hours when continuously driving 20 motors simultaneously.

2.3 Electronics and wiring

For the electronics design we had the following requirement list: wearable, battery–powered, and wireless operation at a 100 Hz refresh rate. To enable integration with the fabric the printed circuit boards (PCBs) have sewing holes as shown in Figure 2.

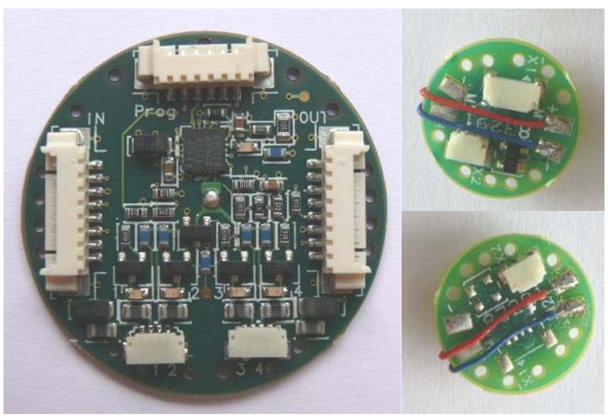

Figure 2: photographs of driver PCB (left), motor PCB 2 with relay connector (upper right) and motor PCB 1 (lower right). Motors (not shown) are placed on the rear.

To drive the motors we selected a microprocessor which has four outputs that are Pulse Width Modulated (PWM). Therefore, the 64 motors were divided into 16 different segments each with its own microprocessor. The segments are daisy chained with a serial bus that starts and terminates at an interface PCB. The distribution of the segments over the body is shown in Figure 1 (lower panels). Each motor is glued onto its own PCB having one or two connectors, motor PCB 1 and 2 respectively. PCB 2 is connected to the driver PCB and relays the current to the motor on PCB 1. We use a PC to control the jacket. The interface PCB connects the PC and the batteries with the jacket. The total weight of one jacket, including electronics and batteries, equals approximately 700 grams.

3. TACTILE STIMULI

We have created a custom LabView™ application that allows us to generate tactile stimuli on various levels of granularity. First, we create different types of shapes that relate to PWM settings which are sent to the motors. Shapes are the building blocks for patterns. Patterns specify at what point in time a particular motor has to run with a given shape. Finally, these patterns are played back on the jacket at predetermined timings or these patterns can be triggered by external events.

3.1 Shapes

The shapes have a 10 ms resolution and their duration is in principle unlimited. The resolution is determined by hardware. The shape amplitude at each 10 ms time step is a value in a range of 25 steps. This amplitude is translated to a PWM output that is sent to the motors. The shape can be any arbitrary waveform as long as all values are positive. Examples of basic shapes are a sine squared wave or an offset square wave.

3.2 Patterns

With the created shapes we can build tactile patterns. A tactile pattern determines for each actuator the timing(s) to start a shape. For this, the timing resolution is also 10 ms. An example of a pattern is a sine squared shape running from the left wrist over the shoulders and neck to the right hand.

4. CONCLUSIONS

We have made a tactile jacket containing 64 independently controllable actuators. This jacket acts as a tactile display upon which tactile patterns can be rendered. A large variety of tactile patterns can be generated with the LabView™ application. These patterns are played back according to preset timings or in response to external events. With this tactile jacket we are currently investigating research questions on tactile stimulation.

5. ACKNOWLEDGMENTS

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