STIMTAC, a Tactile Input Device with Programmable Friction

Michel Amberg[1,3,4], *Frédéric Giraud*[1,3,4], *Betty Semail*[1,3,4],
Paolo Olivo[4], *Géry Casiez*[2,3,4] & *Nicolas Roussel*[4]
[1]L2EP, [2]LIFL, [3]University of Lille & [4]INRIA Lille
Villeneuve d'Ascq, France
michel.amberg@univ-lille1.fr, frederic.giraud@polytech-lille.fr, betty.semail@polytech-lille.fr,
paolo.olivo@inria.fr, gery.casiez@lifl.fr, nicolas.roussel@inria.fr

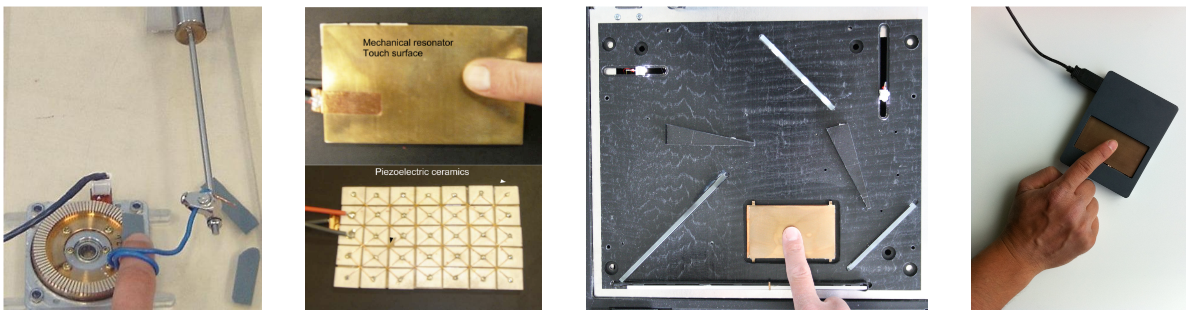

Figure 1: 1D prefiguration (2004), 2D feedback (2007), 2D input & feedback (2008) and compact USB prototype (2010)

ABSTRACT
We present the STIMTAC, a touchpad device that supports friction reduction. Contrary to traditional vibrotactile approaches, the STIMTAC provides information passively, acting as a texture display. It does not transfer energy to the user but modifies how energy is dissipated within the contact area by a user-initiated friction process. We report on the iterative process that led to the current hardware design and briefly describe the software framework that we are developing to illustrate its potential.

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General terms: Design, Human Factors

Keywords: Tactile input, tactile feedback, programmable friction, squeeze film effect

INTRODUCTION
The STIMTAC is a touchpad device that supports friction reduction by means of a *squeeze film effect* [3]. It uses a controlled vibration at an ultrasonic frequency with a few micrometers amplitude to create an air bearing between a user's finger and the device's surface. As the frequency is outside skin mechanoreceptors' bandwidth, one does not feel this vibration but its effect on tribological contact mechanisms: the touchpad feels more slippery as the amplitude is raised. This friction reduction mechanism has notably been used to simulate gratings [2] and facilitate pointing tasks [4].

Other devices and technologies have been proposed to support programmable friction. The LATPaD [6, 5] also uses a squeeze film of air to reduce friction, for example, while Teslatouch [1] uses electrovibration to increase it. But the current LATPaD is rather bulky due to optical position sensing and produces audible noise when active [5]. And while electrovibration is highly scalable, it requires high voltages or users directly connected to ground, and it is presumably sensitive to variations in skin condition, e.g. hydration.

Like the LATPaD or TeslaTouch, the STIMTAC provides the same tactile feedback to any finger moving on any part of its surface. Its output spatial resolution is thus only limited by its input tracking resolution. Our current prototype is compact, powered by the USB cable used for data communication, quiet, and supports precise and reliable finger tracking based on multiple force sensors. In the following, we report on the iterative process that took place over the last seven years and led to the current hardware design. We then briefly describe the software framework that we are developing to illustrate its potential.

ITERATIVE HARDWARE DESIGN
A prefiguration of the STIMTAC was created in 2004 with the free stator of a USR60 ultrasonic motor, a ring shaped resonator providing 3 μm vibrations at 40 kHz (Figure 1, left-most image). A plastic tape was bonded over the machined

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teeth of the stator to level the touched surface. A Linear Variable Differential Transformer (LVDT) was used to detect the user's fingertip position. This solution limited the interaction to a few centimeters along a single dimension, but it already allowed to control and feel the changes in the coefficient of friction.

A second prototype was created in 2007 to produce the squeeze film effect on a 2D surface (Figure 1, second image). Piezoelectric ceramics were coated under a copper-beryllium plate to produce a stationary wave at its resonance frequency. The dimensions of the plate were carefully chosen in order to produce the squeeze film effect. This prototype suffered from two limitations, however: it was still using the 1D LVDT-based finger tracker, and the surface was quickly getting hot due to unoptimized design of the copper plate.

The idea of binding a traditional 2D touchpad to the vibrating plate quickly proved impractical because of interferences with the squeeze film effect. In 2008, we thus replaced the LVDT with a custom-made 2D sensor built from two white LEDs, a set of mirrors and a linear 200 dpi CCD array taken from a fax machine (Figure 1, third image). An on-board DSP was used to compute the centroids of two shadow images created by the user's finger and to send them on a serial line as absolute (x, y) coordinates at a rate of 120 Hz. Yet although adequate from a performance perspective, this optical position sensor considerably increased the device footprint, and heating problems remained.

We then worked on optimizing the design of the plate. This allowed to reduce power consumption by 90% and keep the surface cool while providing the same tactile feedback. In 2010, the optical position sensor was replaced by a set of force sensors, which greatly reduced the bulkiness of the device (Figure 1, right-most image). The serial line was also replaced by a USB connection for both communication and power supply.

Recent work on the STIMTAC has been targeted at the adaptation of its operating principles to off-the-shelf transparent touch sensors. Our latest prototypes notably demonstrate the compatibility of our approach with resistive (Figure 2) and capacitive technologies.

Figure 2: Transparent resistive prototype (2011)

DEMO APPLICATIONS

We have implemented a first series of demo applications using the `Qt` framework and a custom library that moves the system pointer of the host computer according to motions detected on the STIMTAC and adapt its vibration amplitude based on the color of the pointed pixel or the nature of the pointed object.

Pixel-based demo applications display an image and use the grayscale value of the pointed pixel to determine the vibration amplitude, or use a separate hidden image as a "friction map" encoding the desired values. Different synthetic and photographic images are used so that with proper explanations, users can understand the operating principle of the device, how it differs from traditional vibrotactile ones and the kinds of haptic feedback it supports.

Widget-based demos illustrate how these feedbacks can be associated to interactive components rather than pixels. One of them shows a software keyboard that helps users guess a secret word by increasing the coefficient of friction of the next key to be pressed, for example. Another shows a small-sized but fully functional Web browser that increases the coefficient of friction on hyperlinks and buttons to facilitate their acquisition.

Our library makes it quite easy to "augment" existing `Qt` applications with tactile feedback. It also makes it possible to supplement or substitute tactile feedback with basic auditory feedback synthesized using `portaudio` (friction level is linearly mapped to the frequency of a sine wave). This not only facilitated the development and documentation of the applications, but also makes it easier to explain them to a large audience.

REFERENCES

1. O. Bau, I. Poupyrev, A. Israr, and C. Harrison. Teslatouch: electrovibration for touch surfaces. *Proceedings of UIST'10*, 283–292. ACM, 2010.

2. M. Biet, G. Casiez, F. Giraud, and B. Semail. Discrimination of virtual square gratings by dynamic touch on friction based tactile displays. *Proceedings of Haptics Symposium'08*, 41–48. IEEE, 2008.

3. M. Biet, F. Giraud, and B. Semail. Squeeze film effect for the design of an ultrasonic tactile plate. *IEEE Transactions on Ultrasonic, Ferroelectric and Frequency Control*, 54(12):2678–2688, December 2007.

4. G. Casiez, N. Roussel, R. Vanbelleghem, and F. Giraud. Surfpad: riding towards targets on a squeeze film effect. *Proceedings of CHI 2011*, 2491–2500. ACM, 2011.

5. V. Levesque, L. Oram, K. MacLean, A. Cockburn, N. D. Marchuk, D. Johnson, J. E. Colgate, and M. A. Peshkin. Enhancing physicality in touch interaction with programmable friction. *Proceedings of CHI'11*, 2481–2490. ACM, 2011.

6. L. Winfield, J. Glassmire, J. E. Colgate, and M. Peshkin. T-PaD: Tactile pattern display through variable friction reduction. *Proceedings of World Haptics'07*, 421–426. IEEE, 2007.