# Keep in Touch: Portable Haptic Display with 192 High Speed Taxels

**Juan Jose Zarate**
**Olexandr Gudozhnik**
**Anthony Sébastien Ruch**
**Herbert Shea**
EPFL
Neuchatel, Switzerland

juan.zarate@epfl.ch
olexandr.gudozhnik@epfl.ch
anthony.ruch@epfl.ch
herbert.shea@epfl.ch


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## Abstract
We present a portable 12x16 taxel haptic display optimized to rapidly display dynamic graphical information. Each taxel changes state (up/down) in under 5 milliseconds, allowing the entire display of 192 independent taxels to be refreshed in under 2 seconds. The user uses his sense of fine touch to explore the 7-inch display. We demonstrate applications in serious gaming (tactile Pong for the visually impaired), remote collaboration between sighted and visually-impaired users (remote user draws in real-time on the local haptic display), and navigation scenarios. Information can be displayed as a series of static relief images, or as a static image with moving or vibrating taxels. For the navigation task, the outline of a room and furniture is shown first as a static relief, the path to be followed is added as a moving taxels, and the user location is shown as a vibrating taxel. The taxels latch in both up and down states, leading to low power consumption.

## Author Keywords
Haptic display; serious gaming; taxel array; electromagnetic actuators.

## ACM Classification Keywords
H.5.2. Haptic I/O

Figure 1:Using the sense of fine touch, the user explores the dynamic display with his fingertips.

192 fast taxels allow for serious gaming, navigation, orientation, and collaborative computing.

## Introduction
Portable and rapidly refreshed haptic displays would enable visually impaired users to use their sense of touch to interact with data, collaborate remotely, navigate easily in new environments. While similar to a Braille display, the pitch and speed are tuned to display dynamic graphics rather than text.

Making a dense array of taxels with sufficient force and displacement to be easily felt by any user, and that is also low power, fast and compact is a major technological challenge. Several graphical haptic displays have been reported previously, based on electromagnetic 1, piezo-electric, pneumatic 2, dielectric elastomer 3, shape-memory polymer combined with dielectric elastomers 4 actuation principles. Due to the complexity of drive electronics or the lack of performance of actuators, none of those solutions were shown to be scalable, have sufficient performance, and be portable.

On a Braille format, the only commercially available high resolution haptic is HyperBraille, a matrix of up to 76x48 pins driven by piezo-electric actuators with mechanical amplification from the German company Metec, with a retail price of over 50’000 US$.

## Keep in Touch (KiT): 192 taxel haptic display
We present here a scalable and manufacturable fast haptic display (called “Keep in Touch”, or KiT) with 192 taxels on an 8mm pitch with a 5 ms refresh rate per taxel. The device, shown in Figures 1 and 2, consists of an array of 12x16 latching electromagnetic actuators using a novel magnetic shield concept, that enables high fill factor, and eliminates cross-talk.

Key parameters of the KiT haptic display:

- *12 x 16 independently controlled taxels*
- *5 millisecond refresh time per taxel (enables vibration and rapid update of static images)*
- *8 mm pitch between taxels*
- *0.8 mm vertical travel*
- *200 mN holding force (ie, easy to feel)*
- *latches in both up and down states*
- *controlled by Raspberry Pi*

The user feels the pattern on KiT using his fingertips on one or both hands, and provides input using a keyboard or a mouse connected to the Pi.

KiT was developed with low cost in mind, and consists of a matrix of small magnets between two printed circuit boards (PCBs). A 3D printed interface is mounted on the magnetic actuators to provide a smooth and comfortable user experience.

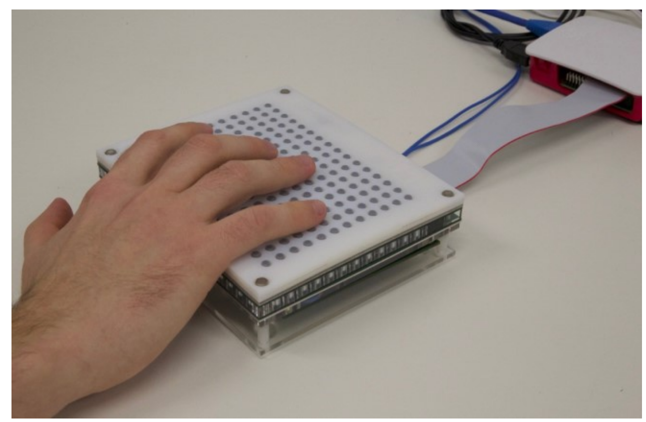

Figure 2: 12x16 haptic display (15 cm x 12.5 cm), and Raspberry Pi (top right). The user touches smooth plastic taxels, driven by an array of 192 high speed actuators.

## Application examples

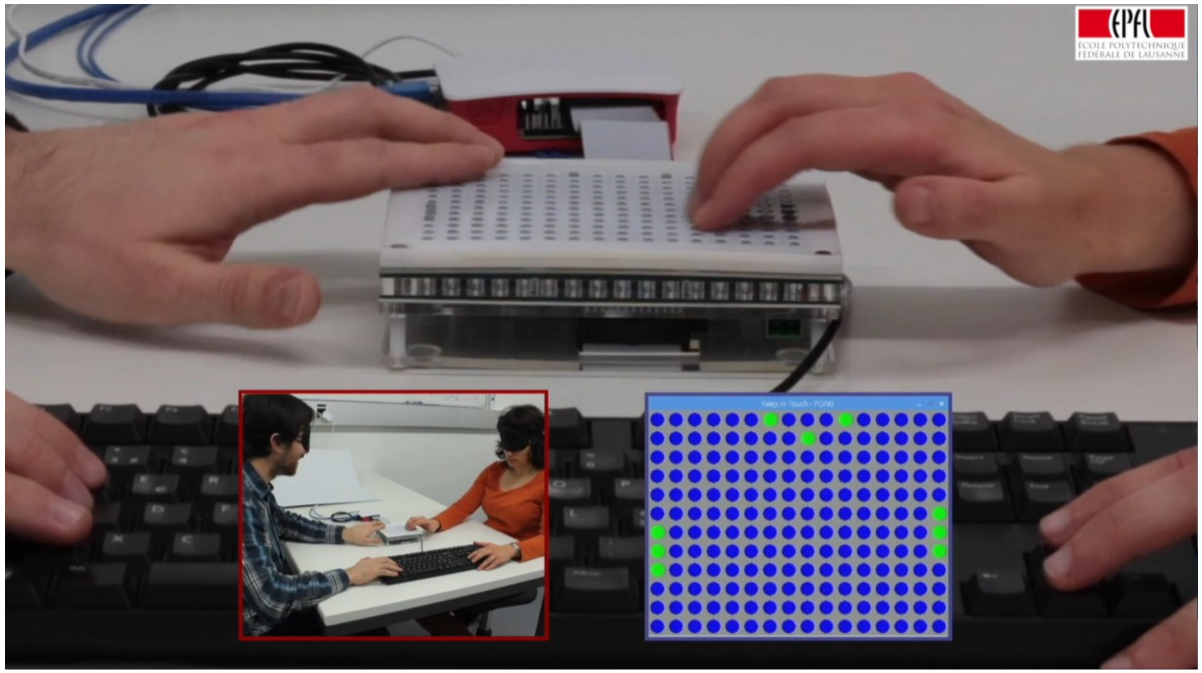


Figure 3: Tactile Pong, as an example of a serious game played on KiT. The two paddles can be seen as 3 raised taxels on the right and left edges, and the "ball" is under the fingers of the player on the right. The two raised taxels at the top are to keep score. The moving taxel vibrates to make it easier to track it as it moves across the display.

*Serious Games*

To illustrate the potential of KiT for serious games, we developed a haptic version of the classic video game Pong. Two users play against each other, each moving a "paddle" by pressing two keys on a keyboard (see Figure 3). The paddle is 3 raised taxels, and the ball is a single vibrating taxel, moving and bouncing off walls and the paddles, until one player does not correctly position his paddle, and the ball exits the display. A top row of taxels also serves to keep score. Each player uses his fingers to explore his half of the display.

The 5 ms response time allows for fast play (the ball can move much faster than a human can react). Vibrating the taxel representing the ball makes it much easier for the players to keep track of the game. The users easily and quickly determined which taxels were up and which were down.

*Navigation scenario*

Exploring a map or the layout of a room is an essential task for mobility, but presents additional challenges for the visually impaired. KiT displays several types of graphical information for navigation.

We start by presenting a map showing only key elements of the room (walls, door, table), see Figure 4. Once the user has explored this, we then add a moving taxel that indicates the path to be followed through the room. Should the user be lost, or to draw attention to a specific point, that location is shown by a vibrating taxel (see associated movie). The user can zoom in and out, and request updates by using a keyboard.

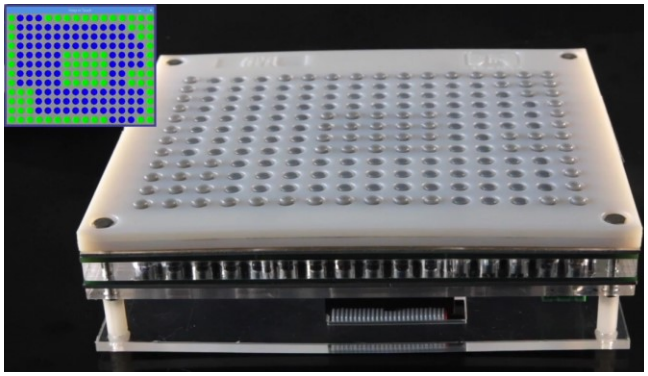

Figure 4: KiT showing a room map (walls, doors, central table) for navigation scenario.

*Remote Collaboration*

A remote sighted user jointly draws a scene with the local visually impaired user. In this manner, two geo-graphically remote people, sighted or not, can jointly perceive graphical information, and both edit the information.

## Conclusions

We illustrated how our innovative haptic display KiT enables several scenarios (serious games, navigation) for visually-impaired users. Our device is unique in combining high taxel count and high speed in a very portable format (mass of 870 g, thickness of 3 cm). The device is very robust, simple to program, portable, and low power (the version we will demonstrate runs on rechargeable batteries).

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We warmly thank Nadine Besse and Samuel Rosset at the EPFL-LMTS for very helpful discussions, advice, and for playing Touch-Pong with us. This work was partially funded by the EPFL and by the EU within the BlindPAD Project (FP7/2007-2013 Grant Agreement No. 611621)

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