

1 Electrotactile FXs

Binary tactile FX is an on/off stimulation controlled by the contact/lack of contact between the fingertip and the interacting object. It uses the central pad of the bottom row of the electrode with a fixed set of electrical stimulation parameters: pulse width equal to 150 μ s, pulse frequency of 100 Hz and a fixed amplitude set equal to the participant's localization threshold for that pad (see Fig 1).

Intensity modulation uses the same configuration as the Binary FX but the intensity of the sensation is controlled by a strength parameter which modulates the pulse width in a linear way between [100 - 300] μ s, which increases as the force interaction with objects increases. The strength is obtained from the interaction and it is treated as a normalized value with a value of zero representing the weakest possible value and one for the strongest (see Fig 2). The tap interaction provides this information by calculating the interpenetration of the real finger into the virtual object with a max value of 5 cm. For the pressing down interaction, the strength is calculated by the compression of the button with a max compression of 5 cm and the sliding interaction uses the horizontal speed of the finger with a max value of 1.1 m/s.

The **Spread pattern** uses the same electrical parameters as the Intensity modulation but modifies the number of active pads based on a strength parameter. Pads are incrementally added outwards starting from the central bottom pad towards an activation where the 6 pads are active at the same time (see Fig 3). To eliminate the discrete nature of adding/removing active pads, they are added/removed in a continuous way by interpolating the amplitude of the stimulation between the sensation and localization thresholds.

The **Clockwise pattern** uses again the same base configuration but a single pad is going to be active based on a clockwise pattern (see Fig 4). The speed of pattern goes in the range [2-10] Hz and is determined by the strength parameter supplied by the interaction.

The **Directional pattern** follows a directional simulation depending on the interaction, e.g., tap interactions do not provide directional information, while sliding interaction activates the electrodes along the direction of sliding (see Fig 5). When directional data is provided, activations made out of 2-active-pads goes left and right based on this value. On top of that, the FX is also coupled to the same strength parameter as the other effects. For strength parameter, the pulse width of the 2-active-pads is modulated in a similar fashion to the Intensity modulation effect.

Finally, the **Random activation** is similar to the Clockwise pattern but instead following a fixed activation order, at every step, a random pad is selected.

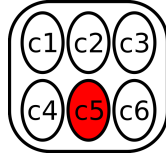


Fig. 1. Binary FX: On/Off of pad C5; amplitude equal to localization threshold; pulse width=150 μ s; frequency=100 Hz

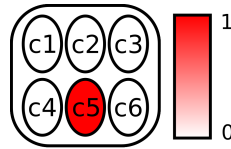


Fig. 2. Intensity modulated FX: On/Off of pad C5; amplitude equal to localization threshold; frequency=100 Hz; pulse width linearly modulated between 100-300 μ s

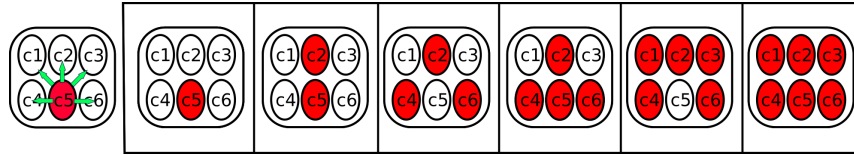


Fig. 3. Spread FX: Dynamic activation based on strength; amplitude interpolated between sensation and localization thresholds; frequency=100 Hz; pulse width=150 μ s

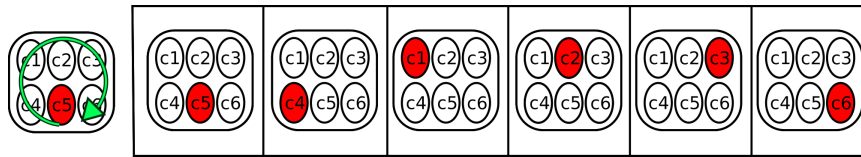


Fig. 4. Clockwise FX: Dynamic activation; speed of the pattern between 2-10 Hz modulated based on strength; amplitude equal to localization threshold; frequency=100 Hz; pulse width=150 μ s

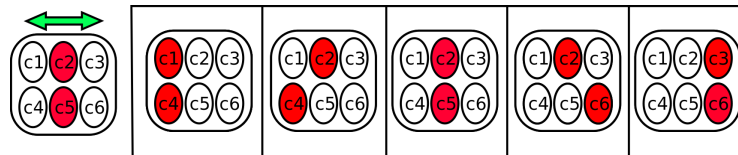


Fig. 5. Directional FX: Dynamic activation; pulse width linearly modulated between 100-300 μ s; amplitude equal to localization threshold; frequency=100 Hz