

# Clip-on Gadgets: Expanding Multi-touch Interaction Area with Unpowered Tactile Controls

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## ABSTRACT

Virtual keyboards and controls, commonly used on mobile multi-touch devices, occlude content of interest and do not provide tactile feedback. Clip-on Gadgets solve these issues by extending the interaction area of multi-touch devices with physical controllers. Clip-on Gadgets use only conductive materials to map user input on the controllers to touch points on the edges of screens; therefore, it is battery-free, lightweight, and low-cost. In addition, it can be used in combination with multi-touch gestures. We present several hardware designs and a software toolkit, which enable users to simply attach Clip-on Gadgets to an edge of a device and start interacting with it.

## Author Keywords

Tactile input, Tangible, physical controllers, mobile devices, multi-touch, toolkit

## ACM Classification Keywords

H5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles.

## General Terms

Design, Human Factors

## INTRODUCTION

Capacitive multi-touch displays are widely used in mobile devices to enable direct interaction and multi-touch gestures. However, virtual keyboards and virtual controls have several user interaction issues. First, virtual controls and users' "fat fingers" [19] occlude content of interest. Figure 1(a)(b) shows the Street Fighter iPhone game UI with a virtual joystick and four buttons, which obscure 22~40% of the screen. Second, virtual controls provide no tactile feedback and require visual attention.

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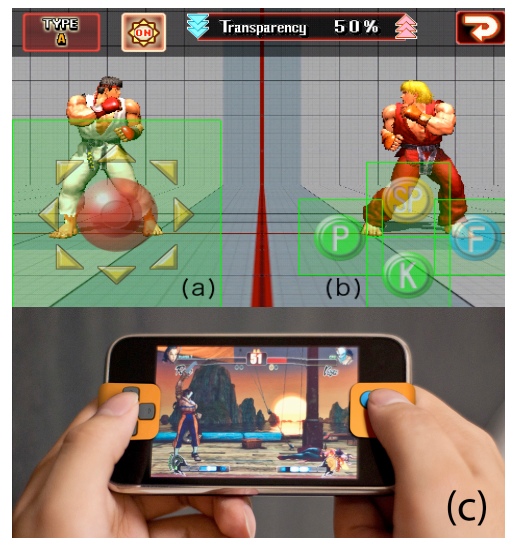


Figure 1: (a) virtual joystick, (b) virtual keypad / buttons  
(c) Clip-on gadgets map user input to touch points on edges of screens to reduce occlusion

External, tactile controllers have been designed to address these issues. Both wired and wireless controllers eliminate occlusion and provide tactile feedback. However, wireless controllers, typically based on Bluetooth, require batteries to operate and are expensive. In addition, they require pairing to use with a device, and also un-pairing if users would like to control a different device. Wired controllers draw power from the mobile devices themselves. They have to route wires from the devices' connectors to the controls, and are generally more bulky. Another type of controller attaches directly to the screen to provide tactile feedback [22]. It makes the occlusion problem worse by completely obscuring the area occupied by the virtual controls.

In this paper, we present Clip-on gadgets that expand the interaction area to reduce occlusion and to provide tactile feedback. As shown in Figure 1(c), they use conductive material to extend users' touches on the physical controllers to touch points along the edges of the multi-touch screens. Thus, they are battery-free and are easy to construct, and can be freely attached and detached.

## RELATED WORK

### Mobile input techniques

The fat finger problem [19] is especially noticeable on smaller mobile devices due to the limited screen size. Offset Cursor [15] is designed to avoid finger occlusion on targets and improve selection accuracy. However, the offset between the cursor and the actual touched point makes it difficult to select contents at the bottom. To solve this problem, callout is usually used to display the occluded area. Shift [23] further improves it by avoiding unnecessary callouts, but, still, fingers block part of the touch screen. The backside of the devices has also been used to eliminate occlusion [1, 7, 8, 19, 21].

Several approaches provide tactile feedback, but do not address the occlusion issue. Several actuator solutions have been proposed to generate vibration at the touch position [3, 4, 10, 14, 16]. E-Sense [18] passes an ultra-low current into the pixel to create a small force to fingertips. Tactile Plus [6] pastes transparent haptic buttons on the screen to provide tactile feeling of buttons. Fling game controllers [22] directs stick on the screen with suction cups. Inside of the controller is a spiral that suspends an electrically conductive joystick to match the virtual controls.

### Expanding physical interaction on touch devices

FlexiKnob [4] is a set of wireless knobs that enables physical rotary control on computer applications that requires fine-tuning controls, such as audio software. VoodooIO [2] is a system that allows users to construct their own physical control panels to fit their personal preferences and input requirements. DataTiles [17] used tagged transparent tiles to integrate digital and tangible interaction on the sensor-enhanced flat panel display. SLAP widgets [24] introduced transparent tangibles that allow users to get tactile feedback and see displays beneath them. The widgets' footprints are detected and tracked using cameras embedded inside the tablet.

There are toolkits to alleviate the pain of hardware and software development of developing TUIs, such as Papier-Mache [9]. It is a toolkit for building TUI using computer vision, electronic tags, and barcodes and also uniforms events across multiple input technologies, thus facilitates technology portability and eases application retargeting. TUIC [26] enables object sensing and tracking techniques on the capacitive touch panels. Since most of the mobile touch devices are use capacitive touch display as the input, we can apply this techniques to extend tangible controls.

The aforementioned studies focus on the scale of desktop or tabletop. In this paper, we expand the dynamic tactile controls on mobile devices.

## SURVEY OF VIRTUAL CONTROLS

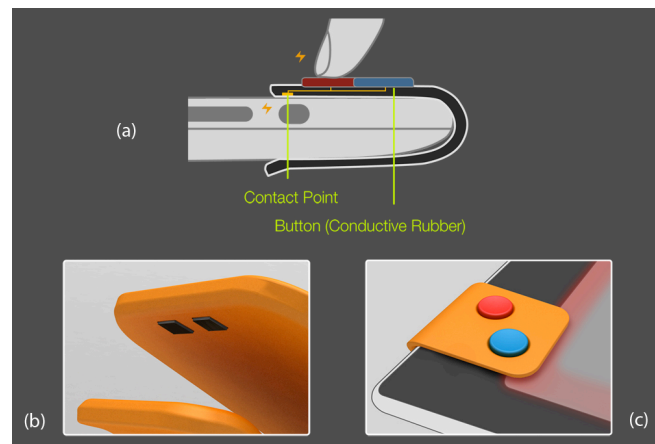
Past studies have reported several typing problems on virtual keys and proposed various solutions [12, 21]. We surveyed the Top 10 arcade games in Apple App Store and

found that there are two types of virtual controls (Figure 1 (a) (b)). One is virtual joystick, and another is virtual keypad/buttons. Users move characters around by moving fingers in different directions on the screen. The direction of movement is determined by the relative position of touch point and the center of the controller. Without tactile feedback, the virtual joystick sometimes does not function as expected because users' fingers traverse the center unknowingly. All virtual controls introduce occlusion problem. Not only do virtual controls overlay on top of the content, users' fingers also occlude the display. Base on our calculation, while playing games with thumbs, the occlusion ratio is about 22~40% on iPhone and 12~14% on iPad, respectively.

## CLIP-ON GADGET DESIGN

Capacitive multi-touch screens sense changes of capacitance by the capacitive coupling effect [27]. When a conductor is placed on the screen and is connected to human body or ground, it changes the capacitance and the position of the conductor is sensed. We utilize this characteristic to build Clip-on gadgets. Figure 2 shows the design diagram of Clip-on gadgets. While pressing the button, the conductive rubber connects user's finger to the contact points and registers as a touch event on the edge of the touchscreen. We decode the touch events to identify the corresponding buttons.

The Clip-on gadgets are un-powered and are easy to carry . They transform the on-screen touch interactions into off-screen tactile interactions, reducing the occlusion ratio down to 5.8~9.6% on iPhone and 0.7~1.2% on iPad.

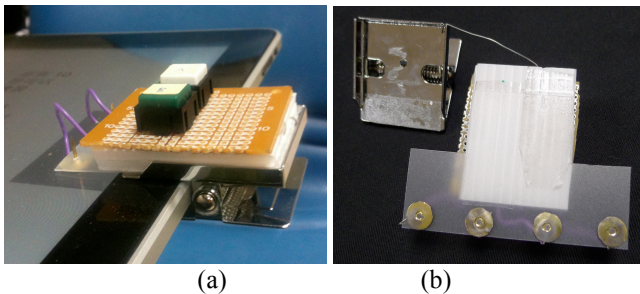


**Figure 2: The design of Clip-on gadget (a) the contact points are conductors and connected to the corresponding buttons, (b) the contact points are arranged on the inward side to contact the touch screen and send the status of buttons, (c) the gadget overlays the edge (3~5mm) of the screen to trigger the touch input**

### Hardware prototyping

Figure 3 shows our clipper-style prototype. In order to provide better tactile feedback, we use physical buttons and

switches. We connect one end to the tack, the other to the metal clipper. The tacks are one to one mapping to the buttons and re-arranged linearly to contact the edge of the touch screen. The size of tack is about 5mm to simulate finger touches. We chose median sized clipper as the control holder and attach some foam on the edge to ensure its stability while clipping to the devices. When the user holds the metal clipper, all the ground ends of the buttons are connected to the human body. Once the user presses the button, it causes touch event at the corresponding contact point (tack). In our experiment on iPad, the minimal size of contact points should be at least 3mm in diameter and the minimal gap between each point is 5mm. These values might be applicable to other touch screens with slightly difference.



**Figure 3: The implementation of clipper-style prototype (a) side view, (b) exploded view**

### SOFTWARE ARCHITECTURE

We developed a toolkit for iOS 4-based devices, written using Objective-C and CocoaTouch APIs included in iOS SDK 4.3. Our prototype devices are Apple iPad 1 and iPad 2 running iOS 4.3. The software architecture consists of three layers and two main components. The three layers works as follows: 1) iOS SDK dispatching touch events to Clip-on toolkit. 2) Clip-on toolkit translating the touch events to the tactile events and dispatches them to the application. 3) The application dispatching the tactile event to the callback functions to perform application-specific logic. The two main components are 1) Clip-on object 2) Detector object.

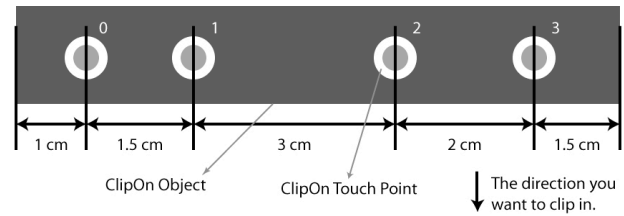
#### Clip-on object

The Clip-on object is the abstract object of the tactile controls. It includes two parameters: 1) a set of contact points on the screen, 2) the corresponding tactile events triggered by the contact points. The developer can load a predefined control in their application or customize one.

#### Predefined controls

Because some controls are commonly used by many applications, we built several predefined controls. For example, a D-pad can be used to control the direction and a knob can be used to control the rotation. Each predefined control maps to a physical Clip-on gadget. For example, a Clip-on D-pad has four buttons: left, right, up, down. So the D-pad object will trigger corresponding events when users

click the physical buttons. We designed the four contact points to have different distance ratios between any two points, so that the contact points can be uniquely mapped to each key (Figure 4).

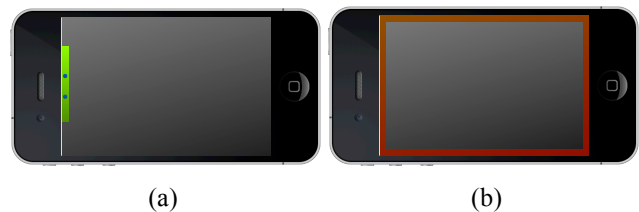


**Figure 4: The layout of contact points**

#### Detector object

The detector object contains an event listener, an event dispatcher and a visual UI element (DetectorView). The detector object is used to detect the touch event triggered by the DetectorView and then dispatch the tactile event to the application. The DetectorView shows the sensing area under the contact points and are used to notify the user to attach Clip-on gadget at that position. The width of sensing area on the edge of the screen is about 5mm, the smallest area for which touch events can be reliably detected. The detector object loads the parameter of Clip-on object to assign the height of sensing area.

We also define two modes of the detector object: 1) fixed-position mode, 2) dynamic-position mode. In fixed-position mode, the screen shows a connector symbol on the left side of the iPhone and enforce user to clip the controller at that position (Figure 5(a)). Developers can customize the position of connector symbols for their own application. In dynamic-position mode, the sensing area is any position along the edges of the devices (Figure 5(b)), so users can clip the gadgets anywhere. The toolkit supports a pairing procedure, which provides on-screen visual hints shown on the screen and asks users to press corresponding buttons to trigger each input.



**Figure 5: two modes of Detector object. (a) Fixed-position mode: clip-on gadget has to be attached to specific positions. (b) Dynamic-position mode: clip-on gadget can be attached to arbitrary positions on the edge.**

### POTENTIAL INTERACTIONS AND FUTURE WORK

In this section, we explore some potential interactions that can be achieved beyond the general-purpose tactile controls such as buttons, sliders or knobs.

### Better learning with haptics

Learning with haptic sensation has been shown to improve learning effectiveness [12]. We propose a piano-learning concept as shown in Figure 6(a). We have built a low-cost keyboard that is unpowered and contains only haptic keys. By using our Clip-on approach, each key is mapped to a touch point on the lower edge of the touchscreen.

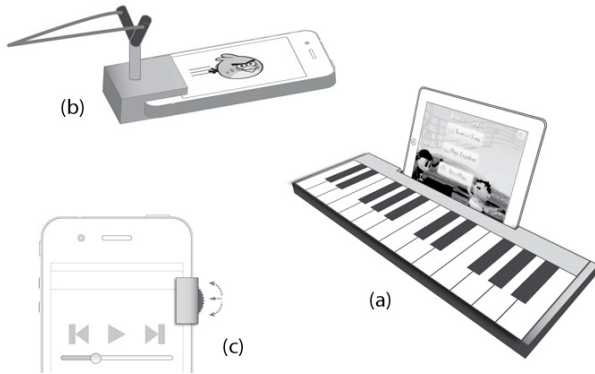


Figure 6: (a) Clip-on piano keyboard, (b) Clip-on Slingshot with force feedback, (c) Clip-on dial

### Force feedback

Although software can generate visual effects, they are still virtual. Haptic controls can provide *force feedback* to enhance experience in certain scenarios. As shown in Figure 6(b), a Clip-on slingshot can augment user experience by providing stretching force feedback in Angry Bird-style games. Users can change the weapon on the touch screen by swiping it and pull the slingshot to fire.

### Single-hand usage

Mobile phones are often used with one hand, especially while walking or holding items in the other hand. Karlson et al. revealed that the vast majority of users want to use one hand for interacting with mobile devices. However, the touchscreens are not designed to support dedicated single-handed use [5] because some areas are hard to reach by the thumb while holding the phone. We propose a Clip-on dial that can provide up, down and click status. As shown in Figure 6(c), the dial can be used to control e-book reading, music player, and other simple navigation. By combining audio or vibration feedback, it enables users to use the devices eyes free.

### Collaboration

Larger touch screens support collaborative work and gaming with multiple people. However, having more fingers on the screen leads to worse occlusion problems. Since the Clip-on gadgets can be easily attached next to the screens, they enhance sharing experience. Figure 7(a) shows four Clip-on gamepads are attached to an iPad to support 2-player games.

### Enhancing Productivity

By integrating tactile and multi-touch interactions, we can enhance input efficiency. Figure 7(b) shows a Clip-on Numpad to support number input for accounting. The physical keys can be used with minimal visual attention, which help users to quickly key in numbers.

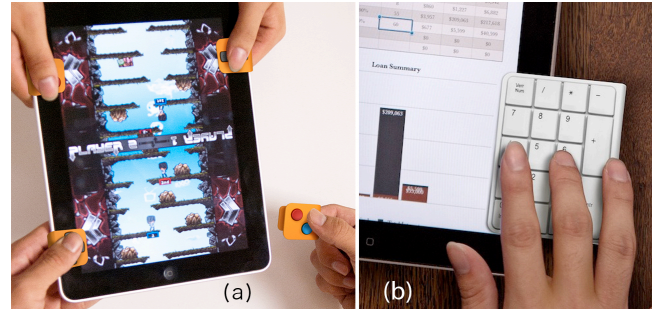


Figure 7: (a) Collaborative gaming. (b) Clip-on Numpad

### CONCLUSION

We have presented Clip-on Gadgets for multi-touch mobile devices that expand the interaction area with physical controls. Clip-on Gadgets do not require power, battery, or wireless connections to operate, and the physical controls can be used with minimal visual attention. Users can simply attach the gadgets to the edge of the device and start to interact with it. In addition, tactile and multi-touch input can be combined to support more flexible interactions in the future. Current version of Clip-on gadget uses one-to-one mapping from physical buttons to touch points, and we plan to design touch patterns that can support more types of inputs in the future.

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