# Review of “TUIC: Enabling Tangible Interaction on Capacitive Multi-touch Display”

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**Abstract**—TUIC is a technology that affords direct, tangible manipulation on unmodified capacitive multi-touch displays. TUICs are economical to produce, and can be detected using existing software due to their simulation of human finger touches in order to interface with the capacitive multi-touch display.

**Keywords**—Review, Tangible User Interface, Capacitive Multi-touch Display.

## 1 Introduction

TANGIBLE User Interface (TUI) is the physical manipulation of digital information. In a TUI, users directly manipulate physical objects in order to control a computer system. Examples include the computer mouse, building blocks on a smart surface, etc.

Most TUIs have been implemented on diffuse-illumination multi-touch displays, such as Microsoft’s Pixelsense [1]. Such displays require a camera, and usually require infrared light source(s).

TUIs for diffuse-illumination displays typically involve simple optical techniques, such as infrared reflectors (which can be used to create tagged, detectable objects [2]) or fiber-optic light-channels (allowing tags to be read from the layers in a stacked 3D structure, such as children’s building blocks [3]).

In contrast to diffuse-illumination displays, capacitive multi-touch displays provide many of the same interaction experiences as diffuse-illumination displays, yet are thinner and lighter. There low weight and thinness afford their extensive use in the mobile computing market.

### 1.1 Motivation

The rise of the personal computer has replaced push-buttons, knobs, sliders, etc. with on-screen skeuomorphs due to the costs (design, engineering, manufacture, shipment) of delivering such physical interfaces.

Yet such physical controls provide a level of haptic feedback traditionally not provided by their computer-rendered replacements; such feedback allows a user to manipulate the controls without actively regarding them, and in many cases may divide their attention among this manipulation and other tasks.

Market share of capacitive multi-touch displays is greater than any other digital multi-touch technology. While many TUIs have been implemented for diffuse-illumination displays, scarce few have been developed for capacitive multi-touch displays.

Current approaches to TUIs on capacitive multi-touch surfaces require additional sensors. For example, Wacom’s “pen and touch” tablets Requires an additional layer in the display to detect the pen.

## 2 Contributions

TUIC [4] allows a TUI to be implemented on unmodified capacitive multi-touch displays (such as the iPad, many smartphones, and 3M’s 22-inch M2256PW display).

TUIC translates a user’s actions into simulated finger-touch events on the underlying capacitive multi-touch display. Finger touches are simulated using two approaches:

- Passive: a conductor contacts the screen, triggering a touch event.

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- Active: a battery-powered device causes many touch events per second to be registered by the display.

TUIC has also developed reliable object identification in the 2D-spatial ("TUIC-2D") and 1D-frequency ("TUIC-$f$", "TUIC-hybrid") domains for the classes of capacitive multi-touch displays used by the iPad and 3M's M2256PW display. This provides for a set of unique tags, the number of which increases with object size.

# 3 Analysis

Advantages:

+ Physical objects are detectable by unmodified capacitive multi-touch panels.
+ The position and orientation of these objects are detectable.
+ 2D-spatial approach is passive. No batteries required.
+ 2D-spatial TUICs are very cost-effective to manufacture. The conductive pad could be a screw, painted on, etc.
+ 1D-frequency (active) approach has >90 days of battery life compared to the 8-hr life of the näive approach
+ 1D-frequency TUICs are <3USD[1] to manufacture.

Disadvantages:

– TUICs occlude the user's display.
– Lower bound on inter-contact distance (5mm). This causes TUICs to grow in size in order to support more unique IDs.
– Lower bound on detectable frequencies (15ms half-cycle interval). This also affects the minimum size of a TUIC for a given number of unique IDs.
– Upper bound on concurrent touch events (10-20). This places an upper limit on the number of concurrent TUICs in use.
– 1D-frequency approach requires >100ms startup time.
– There are large variations in the frequency detected by the capacitive multi-touch display. This is ameliorated by both sensing state toggle instead of individual state, and by integrating over a large time window.

1. MSP430, 120mAh battery, components.

## 3.1 Improvements

**ECC.** The author's approach to unique ID generation leave no leftover bits for error-correction codes (ECCs). Such ECCs are commonly used by other object-recognition systems since they allow partial degradation of the object, as well as environment noise to be filtered out. This can speed up detection (fewer retries), reduce false-positives, and enable damaged objects to continue to be detected.

**Encoding.** The approaches used in the 1D-frequency domain only consider equal intervals for each state. Varied-intervals could be employed to encode more information. In the 2D-spatial domain, the inter-conductor distance could be varied in order to encode more information.

**Density.** Both the size of the TUICs and the number concurrent of TUICs are lacking. The scheme used in the TUIC-2D approach is not space filling, it leaves long stretches of unpopulated spaces.

Size aside, the number of conductive pads (3) for the smallest device (the TUIC-hybrid) only allow for 3-6 such devices in concurrent use. Some technique, such as round-robin scheduling, etc. could be employed to increase this number of concurrent TUICs in use.

**Start-up time.** Some combination of the improvements suggested under ECC, Encoding, or Density should provide more bandwidth than the current prototype. The start-up delay for active-type TUICs must be brought below 100ms.

**External sensors.** In the case of the active-approach TUICs, we can consider additional sensors whose state can be encoded and transmitted to the device through the simulated-touch approach outlined in the paper.

**Minimize occlusion.** The authors suggest a clip-on device that just barely touches the edge of surface [4]. This minimizes the screen occlusion, while still providing a TUI. Another approach would be to reduce the size of the device, discussed under Density.

## 3.2 Applications

The authors discuss three applications [4]:

- Replace menus with physical objects

- Call up a widget
- Physical authentication key

**Replace menus with physical objects.** A public kiosk is installed with a capacitive multi-touch display. TUIC-2D objects are provided for the public to use to navigate the kiosk, due to their low cost of manufacture and short expected-lifespan. The users may then use these objects in the place of an on-screen menu in order to access information.

In the example given in the paper [4], an art gallery provides a kiosk with TUIC-2D objects with the picture of an artist, artwork, etc. on the top of the object. The user then places the TUIC-2D on the kiosk to browse and view the kiosk's content.

**Call up a widget.** A TUIC may contain additional components, such as a knob or button, that when placed in the display display a widget that can be controlled with the TUIC. Examples include volume controls, keypads, sliders, joysticks, etc.

**Physical authentication key.** A key-shaped TUIC can be made, and an large amount of data can be encoded onto the position of up to 10 passive conductive pads, and an even larger amount if using the active-approach. These keys can be issued to an individual in order to authenticate with a service, rather than inputting a password.

## 4 Conclusion

TUICs are notable for two reasons: they are cost-effective to manufacture, and they piggyback on popular and ubiquitous capacitive multi-touch displays. While this technology offers advantages over traditional finger-based input, it remains to be seen if these advantages will enjoy enough popularity to foster widespread adoption.

## References

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