“Feel the Force Pi”

(with apologies to Star Wars fans)

How UltraTouch force-sensitive touch displays provide new and exciting user interfaces, vastly improved user experience and improved control functions for the Raspberry Pi 5

Traditional Touch Display Modules

Touch Display Modules (TDMs) provide a flexible and versatile means of interacting with a Raspberry Pi 5. It can display information or content for consumption like a movie and detect the location and lateral movement of up to ten fingers. These finger gestures can be used to provide control functions for the Raspberry Pi 5 and, with an appropriate user interface, can even entirely replace the keyboard and mouse as input devices.

Finger location and tracking can be achieved using multiple technologies. The most prevalent is projected capacitance (PCAP). Most of the time it works extremely well, being fast, accurate and able to report finger location with sub millimeter precision. Hence it’s pretty much universal dominance in consumer TDMs. However for more demanding environments like outdoors, industry, medical, aerospace etc. a PCAP TDM might not always function reliably. For example, a user could be wearing gloves or gauntlets, there might be rain, snow, frost, mud, oil, chemical, body fluids or other indescribable substances on the display. There might also be a need to ensure the control gesture is deliberate. PCAP works by detecting the presence of a moderately conductive object on the display. This need not be a finger. Pocket dialing by a mobile phone can be embarrassing, whereas accidentally launching an intercontinental ballistic missile is more broadly inconvenient.

UltraTouch User Interfaces (UI)

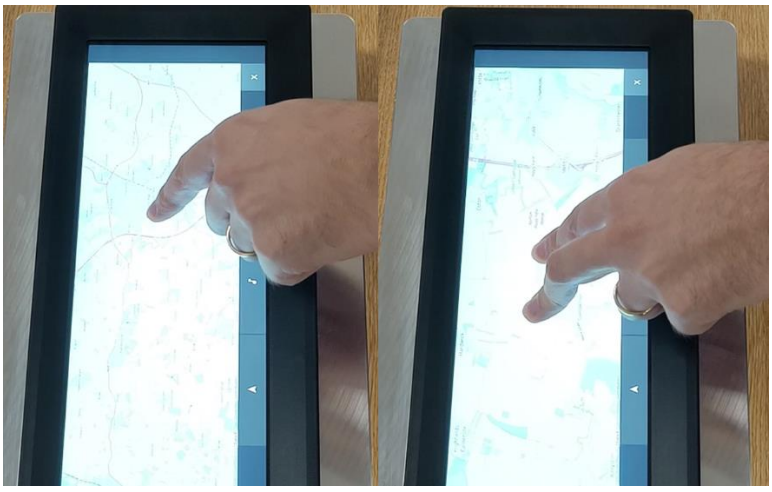
At it’s most fundamental, a PCAP user interface can only report one variable to the Raspberry Pi 5; namely the finger location(s). By adding a temporal attribute it is possible to determine whether the finger location is static, i.e. a tap gesture, or is moving e.g. a swipe gesture. Despite this limitation it is relatively easy to construct complex user interfaces with virtual buttons, switches, sliders, rotary knobs and gestures such as ‘pinch to zoom’.

UltraTouch TDMs incorporate a force sensor. This adds a whole new dimension to the user interface. The force sensor is not a 'weighing scale' but a whole area and exceptionally rugged solid state sensor built into the display itself that is coupled to the PCAP system. Whereas a PCAP only TDM reports finger location (XY co-ordinates), an UltraTouch TDM provides finger location and pressure (XYZ) to the Raspberry Pi 5. The Microsoft Human Interface Device (HID) protocol already contains a container for 'pressure', which the Raspberry Pi 5 can poll to extract the data. To simplify use, the UltraTouch system contains a register for a force threshold (adjustable roughly 50gf – 600gf) and the HID pressure container is either empty (null) if the force is below threshold or populated if the force exceeds the threshold.

An UltraTouch TDM reports two variables to the Raspberry Pi 5 – finger location(s) and pressure either below or above threshold. If multiple fingers are pushing on the TDM the detected pressure is not the aggregated total (as would be the case for a weight scale sensor), but a pseudo-average of the force applied by each finger.

The availability of force as an input parameter opens the way to a plethora of new and exciting user interfaces. Virtual buttons, sliders, switches etc. can now have force enabled functions in addition to and in combination with all of the usual PCAP control functions. Some of the new possibilities include:

- Push select (force above threshold launches action)
- Push hold (something only happens while button is pressed)
- Staircase push (different actions initiated by different forces, typically a maximum of three)
- Ramp push (system response is proportional to the force)
- Drag push (drag then push to confirm new setting)
- Push drag (drag only possible when force threshold exceeded)



Automotive infotainment system in navigation mode demonstrating one finger push to zoom in, two finger push to zoom out with the rate of zoom being force-dependent

Some user interfaces made possible by UltraTouch TDMs are quite intriguing. Many will be familiar with using 'pinch to zoom' to alter the scale of a map. However trying to use this gesture on a touch screen in a car is not easy. The attention of the driver should be on the road ahead,

while the motion and vibration of the vehicle makes the gesture difficult to control especially if the interface additionally provides map rotation. A user interface that is far simpler, easier and reliable to use is 'push-zoom' . Push anywhere with one finger and the map zooms in, push with two fingers and the map zooms out. The rate of zoom can even be made proportional to the force applied. Once experienced, the natural and intuitive nature of this interface makes it difficult to accept anything less.

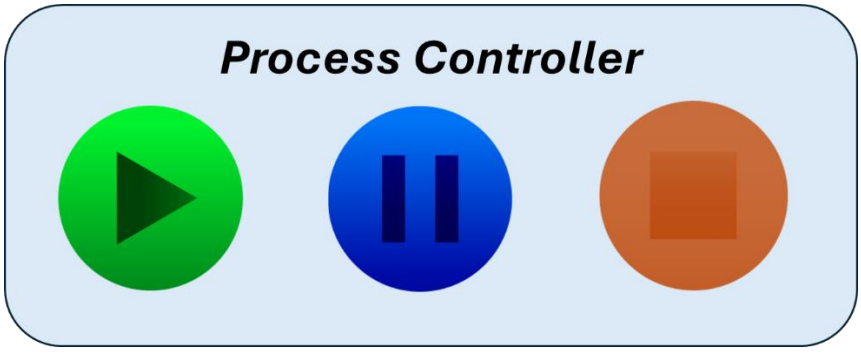
UltraTouch User Experience (UX)

A touch display module is a cold, hard, inanimate slab of glass. Cozying-up to an object like that is not something humans do willingly. Humans are very reliant on the senses for emotional well-being and of the senses, touch is by far the most important. Emotions are called "feelings" for precisely this reason. The one thing humans like to touch most is human skin. Caressing, hugging, holding hands are all emotionally satisfying things to do. Quality and luxury are associated with surfaces that are warm, soft and slightly compliant because they substitute for another human.

Humans are naturally wired to impart information using force as a vector. Holding hands gently conveys happiness, tightly gripped equates with anger and fear. We unconsciously use force when interacting with machines as well. If the button on an App is unresponsive, the natural action is to push it again, but harder. On a PCAP only TDM pushing serves no purpose. However on a UltraTouch TDM, detection of a high force could be used to trigger a system reset or other intervention.

Consider three process control buttons marked Start, Pause, Stop. The natural way to engage with these buttons is different for each:

- Start is associated with a push-hold gesture. Depending on the nature of the beast under control, the hold will often be sustained until there is confirmation by sight, sound or another sense that the process has started.
- Pause is light tap because pausing is an optional event so the investment in the decision is small.
- Stop is a command, so will be enacted by a firm push. The more urgent it is to stop the process, the harder the push will be.



Simple control interface. Desirably the three virtual buttons have different force-touch characteristics to meet the expectation of how they need to be operated.

Using an UltraTouch TDM, the force sensitivity can be exploited to make the button actions mirror expectation. Doing so results in a more intuitive and pleasant to use interface and in turn make the user experience emotionally more satisfying and gratifying

UltraTouch system control

Human control of a computer system, such as the Raspberry Pi 5, or indeed a system controlled via a computer carries risk. The purpose of the computer is to provide control options to the human overseer. Where the human machine interface is a TDM, the computer has no way of knowing whether a command it receives is deliberate or indeed human at all. UltraTouch has the ability to address both concerns making it ideal for mission-critical applications and other system control applications where safety is important.

PCAP responds to any moderately conductive object applied to the display. This propensity is increased if the gain is boosted to permit function with gloved fingers. UltraTouch requires the applied force to exceed the set threshold before it is recognized as an event. This, when coupled with PCAP to define the event location on the TDM greatly improves the security against accidental triggers.

UltraTouch provides one further security guarantee. Human force-touch has a very distinct and complex temporal profile. Using advanced algorithms it is possible to detect the signature of human finger touch and reject other touch events even in instances where the force threshold is exceeded. Despite the complexity of the signature analysis required, the analysis can be completed in tens of milliseconds.

UltraTouch provides two gates that a force touch event must pass before it is notified to the Raspberry Pi 5. Combined, they greatly improve security of system control when using a TDM as the human machine interface.

Raspberry Pi 5 to UltraTouch TDM connectivity

Connecting a Raspberry P 5 to an UltraTouch TDM is dead simple since both the display and human machine interfaces are ‘plug and play’. The display requires HDMI video while the PCAP and force communication with Raspberry Pi OS is by USB. Raspberry Pi OS, (Debian 12 bookworm, kernel 6.6, released 24 July 2024, the current version at time of writing), handles the relevant part of the Microsoft HID protocol to report the ‘pressure’ associated with touch events.

Example of a GUI written to demonstrate the difference between PCAP only touch and force-touch on the same UltraTouch screen. For the PCAP switch the application ignores any force values so the switch can be operated with the lightest touch. The switch on the right requires a push of around 300g to actuate, similar to the mechanical switch depicted.

There exists a vast range of tools that can be used to develop graphical user interfaces (GUI). A popular one is Qt for Python. Raspbian OS uses a static Qt for Python library based on v6.4.2. Unfortunately, an issue in this library means that the Microsoft HID 'pressure' container is incorrectly handled. To update the Qt for Python library it is necessary to create a Python virtual environment to enable upgrade to the latest version. Instructions how to do this are provided by the developers of Qt [1]. Using this approach, GUIs can be written that exploit new features of force-touch sensitivity.

UltraTouch TDM Example

UltraTouch RX-TM-070845A-1.0 is a 7" touch display module (TDM) with true force sensitivity, intended for consumer, industrial agricultural and medical applications. It combines a premium, full color IPS LCD display (1280x720) with a rugged, whole-area, solid-state touch-and-force sensor. The PCAP system is tuned by default for thin gloves and light surface contamination, while the force threshold is adjustable between 50gf and 600gf. The display incorporates a high brightness backlight (1,000cd/m^2) making it sunlight readable in many environments. The black print is fully symmetric and the absence of any moving parts means the display can be mounted and used in any orientation with no change in force-touch sensitivity. A chemically strengthen cover glass together with industrial reliability, lifetime and temperature range plus the ability to meet IP and IK ratings with suitable mounting and enclosure ensures it can be used in a wide range of environments. It is designed to be 'plug-and-play' with Windows 10 and above and most Linux kernels, including Raspberry Pi OS, used with Raspberry Pi 5 single board computers. RX-TM-070854A-1.0 delivers fast and reliable human finger force-detection for applications where value is placed on improved user interfaces, better user experience and where system control demands a high-level of confidence in the user intent.