Touchscreen usage with upper limb prostheses: initial explorations

Phil Day[1], Elina Jokisuu[1], Maggie McKendry[1], Scott Edward[2], & Rami Abboud[3]

[1]User Centred Design, NCR Corporation, Dundee, [2]TORT Centre, Ninewells Hospital, Dundee, [3]Department of Orthopaedic & Trauma Surgery, University of Dundee

ABSTRACT

This paper describes a formative investigation into the use of projected capacitive touchscreens with upper limb prostheses. A difference in performance was found between two types of touchscreen, and also between different varieties of prosthesis; although the methodology means that further study is required as the prostheses were held in a simulated contact rather than actually worn in a realistic manner.

Even with these caveats, this early work demonstrates the potential problem that exists in using touchscreens with a prosthetic device, and explores some possible solution areas.

KEYWORDS

Touchscreen, prosthetics, usability

Introduction

Touchscreens are used in a number of devices, including smartphones, tablets and self-service terminals such as kiosks and automated teller machines (ATMs). There are many different technologies that can be used in detecting a finger touching a screen, such as resistive, infra-red, surface acoustic wave, capacitive, and surface capacitive. However, some of these technologies have serious drawbacks when being used in a public setting such as in self-service; for instance, infra-red can have problems with sunlight, and surface acoustic wave technology does not work well when it rains, or with lots of dust or dirt on the screen. Others have aesthetic or durability issues; a resistive touchscreen, for example, has small plastic beads that are visible on the display area, and also wears out when frequently used. Similarly, a surface capacitive touchscreen can also wear out as the active element is on the front of the display. For these reasons, projected capacitive (PCAP) touchscreens have particular benefits for use in self-service, and have also been widely used in smartphones and tablets (Fihn & Phares, 2014).

However, PCAP touchscreens do not always work well with upper limb prostheses; the construction and particularly the electrical characteristics of the prosthesis have a significant impact on whether a touch is detected. Furthermore, the need for and use of prostheses is growing, mainly due to populations ageing and the increased prevalence of certain medical conditions, such as diabetes and stroke, which may necessitate amputation of limbs (WHO 2017). This means that compatibility issues with touchscreens are likely to become more common.

Unfortunately, there is very little research conducted to investigate the compatibility of prostheses and touchscreens. Research exists about touchscreen use by people with motor impairment in upper limbs, for example people with spinal cord injury, multiple sclerosis, cerebral palsy, essential tremor or muscular dystrophy, and generally focusses on difficulties of speed and accuracy in touchscreen interaction (e.g. Anthony et al., 2013; Duff et al., 2010; Guerreiro, et al., 2010; Sarcar et al., 2018; Trapp et al., 2014). None of the previous studies we encountered involved people with upper limb prostheses. Neither have we have been able to find any systematic studies of the use of different prosthetics on different touchscreens. New prosthetics solutions are constantly being developed, for example touchscreen-compatible leather and textiles, a spray of nano-particles that helps the prosthesis material react with touchscreens, and touchscreen-compatible digits that can be attached to existing prostheses (Weinsier, 2014; Gill, 2018; Macduff, 2012). However, it should also be noted that many of the advances in prosthetics will not be available to large numbers of prosthetics users: users in developing countries may only have access to the most basic prosthetic solutions (WHO, 2017).

The problem

There is a significant level of variability in upper limb prostheses in terms of appearance, materials, articulation, and usage. Sometimes they include a variety of terminal devices that can be attached (such as grippers, hooks, cosmetic hands or specialised terminal devices for a specific profession or hobby). The design of a prosthetic device can be either passive (purely cosmetic, without any articulation), mechanical (body powered, i.e. with connecting cables and harness the terminal device can be moved and manipulated by moving the shoulder or arm), or myoelectric (the terminal device is controlled using signals from muscles of the residual limb) (Comprehensive Prosthetics & Orthotics, n.d.). In addition, the interface between the body and prosthesis is often modified with additional material (chamois leather, cotton or silk 'sock') to reduce discomfort, thus adding to the variety of prostheses. Anecdotal evidence from the field has indicated that different generations of touchscreen appeared to have different responses to a given prosthesis; with the prosthesis reported to work with one touchscreen and not with another (both PCAP devices).

Finding a solution that works for this variety of prostheses is rather challenging, and some initial exploration was needed to better understand the scope of the problem.

Investigation & analysis

We partnered with the TORT centre (Tayside Orthopaedic and Rehabilitation Technology Services), Ninewells Hospital, which is a local facility with a dedicated prosthetics and orthotics department, co-located with a university research group (the Department of Orthopaedic & Trauma Surgery, University of Dundee), and thus offering a blend of practitioner knowledge and academic research expertise in the area of prosthetics.

The first exploratory investigation took the form of a formative expert review. None of the investigators were amputees; each prosthesis was held in a way to try and replicate the level of body contact that may be the case in reality, but we recognise that this was not fully representative (Figure 1).

A number of different types of upper limb prostheses were used in the review. The prosthesis types were selected based on the advice of the principal prosthetist at the partner facility to cover a range of commonly used prosthesis types. The types of prostheses included in the trial are listed below, and can be seen in figure 2:

- Lower arm hook (passive gripper)

- Upper arm hook (passive gripper with elbow joint)
- Passive cosmetic hand with mechanical carcass (pinch grip, internal spring)
- Cosmetic hand with internal copper wires (so fingers hold their shape)
- Cosmetic hand with internal & external copper wires (wrist)

Figure 1: Prosthesis being held with simulated skin contact

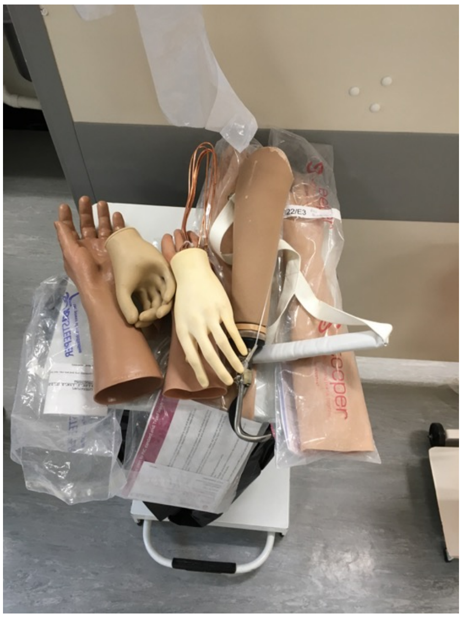

Figure 2: Prosthetic devices used in review

We used two different touchscreens in this review: a previous generation of ATM display and the current one. The older (previous generation) screen was a self-capacitive single-touch PCAP screen. This could only detect a single digit at a time, but tended to give a stronger signal when a touch was detected. The newer (current generation) screen was a mutual capacitive multi-touch PCAP screen. This could detect up to 10 digits at a time or gestures, but tended to generate a slightly weaker signal than the self-capacitive system due to the much more complex detection algorithm used in multi-touch. We also considered two different detection thresholds with the newer multi-touch screen: an interior threshold which is more sensitive and an external threshold which is less sensitive as it needs to be able to handle rain and other weather-related issues. The threshold comparison was done in order to quantify how the detection performance could be made more comparable between the old single-touch and newer multi-touch systems.

Two different use cases were investigated with the touchscreens:

- touching an on-screen menu item (single touch, with fairly large target areas) (Figure 3)
- entering a signature on-screen (writing with your finger, in a similar way to the system that is used to sign for receipt of goods by some delivery couriers) (Figure 4)

In each case, the investigator used each prosthesis in turn with each touchscreen. Observations were taken of whether the touch was detected with a light touch (i.e. small surface area such as the end of the terminal device), then a heavy touch or large surface area (such as the side of the terminal device). In each case, the observations were assessed on a 4-point scale, described in Table 1.

Table 1. Classification of expert observations

Excellent	Very good touch detection for single touch and gestures, no broken lines for gestures/signature
Good	Very good touch detection for single touch, but gestures give broken lines
Poor	Most single touches are detected, but only with a large contact area (side of prosthesis) driving awkward hand/arm postures
Very poor	Only occasional single touches are detected, even with a large contact area

Figure 3: Single touch task

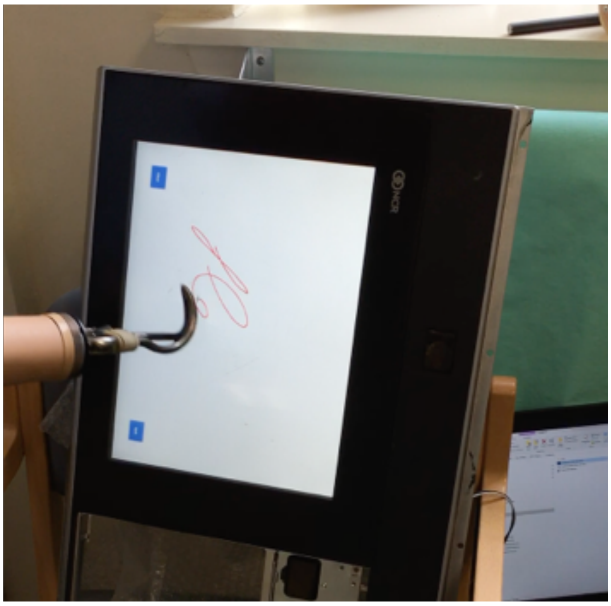

Figure 4: On-screen signature task

Finally, if no touch was detected, the investigator then added an active stylus (Adonit© Pixel)[1] to the prosthesis to assess whether this would improve touch performance (Figures 5 and 6).

[1] Adonit© Pixel was selected after an expert review of a range of active and passive styli; the details of the review are beyond the scope of this paper.

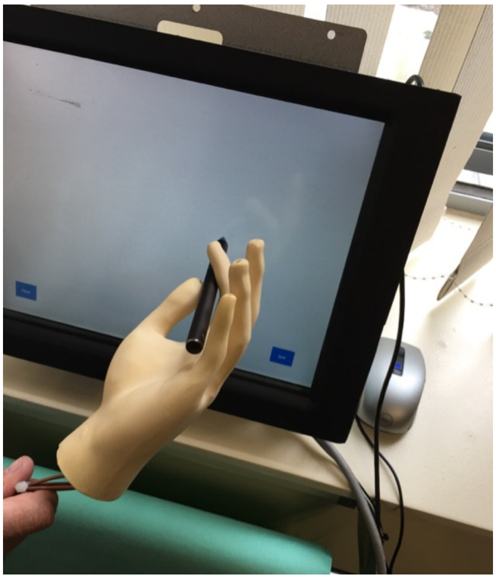

Figure 5: Single touch with active stylus

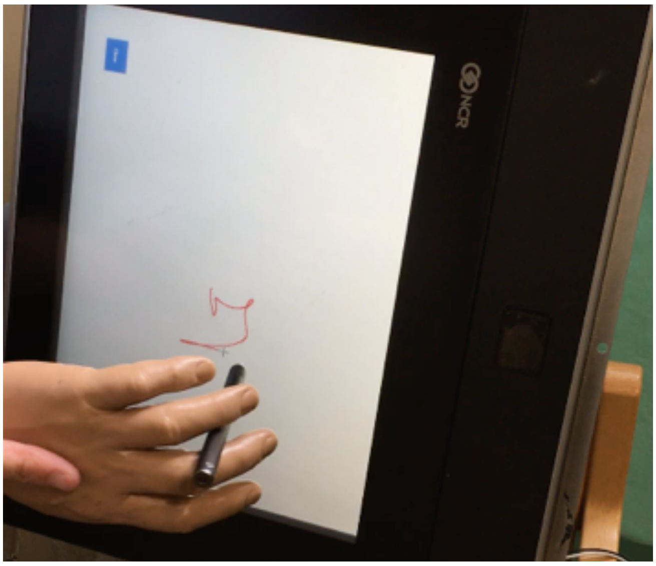

Figure 6: Onscreen signature with active stylus

Results and output

The results, summarised in Table 2, show that touch performance with the previous generation single touch screen was better than the current generation multi-touch screen. However, the current generation multi-touch screen is significantly better than either when configured for an interior threshold.

Table 2. Results of the expert review

	Previous generation single touch screen, exterior	Current generation multi-touch screen, exterior	Current generation multi-touch screen, interior
Upper arm hook	No touch	No touch	Excellent
Lower arm hook	Poor	No touch	Excellent
Passive cosmetic hand with mechanical carcass	Poor	Very poor	Poor
Cosmetic hand with internal copper wires	No touch	No touch	No touch
Cosmetic hand with internal and external copper wires	No touch	No touch	No touch

When adding an active stylus, touch performance is significantly improved with each touchscreen type (Table 3).

Table 3. Results of the expert review when an active stylus is added

	Previous generation single touch screen	Current generation multitouch screen, exterior	Current generation multitouch screen, interior
Upper arm hook	Good	Good	Excellent
Lower arm hook	Good	Good	Excellent
Passive cosmetic hand with mechanical carcass	Good	Good	Excellent
Cosmetic hand with internal copper wires	Good	Good	Excellent
Cosmetic hand with internal and external copper wires	Good	Good	Excellent

These initial investigations were useful in validating that there was a difference in performance between the two types of touchscreen, and also in defining a range for the detection threshold that would appear to give a similar level of performance between the two systems. The use of an active stylus appeared to help; in general, those prostheses that did not generate a touch on their own did generate a touch when using an active stylus.

However, these early results also demonstrate the need for more empirical work. We are in the process of planning for a larger user test with upper limb amputees who wear a prosthesis; either unilateral or bilateral amputees. This should enable us to validate some of the assumptions in this exploratory work and to test a wider range of projected-capacitive implementations, including new concepts from touchscreen vendors claiming to offer better performance with prosthetic limbs.

Impact & implications

Our initial investigations have found that there does appear to be a potential issue for some types of prostheses when used with a PCAP touchscreen. Performance also seems to be influenced by the implementation of the touchscreen. However, this study was extremely limited in scope, and we cannot place a great deal of confidence in the results as the prostheses were held in simulated manner rather than actually being worn. Further study is required with participants wearing upper limb prostheses to validate these findings and to quantify the relative performance between different types of implementation of PCAP touchscreens.

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