# Development of Interaction Techniques for Touch Screens

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## ABSTRACT

Touch screens offer many advantages but suffer from several critical limitations. Many research groups are constantly working to resolve the problems. This research review describes development of interaction techniques for touch screens. Seven separate research groups identified problems with touch screens and developed new designs and techniques to overcome its limitations. The identified issues are inaccuracy and slow speed in selection of small targets, problem with zooming, low input bandwidth and difficulty in using touch screens for disabled people. Experiments of the research groups are examined and compared. Reviewing the literature suggested that selection techniques develop to be more intricate and sophisticated. Progress in selection strategies is possible due to the development of supporting hardware and advances in sensing technology.

## INTRODUCTION

At present, touch screen (screen, table, wall, etc.) use is widespread in public installations, such as information kiosks, automatic teller machines, ticketing machines or gambling machines (Albinsson & Zhai, 2003). Touch screens are appealing to general public as placing a finger (or a pen) onto a screen to make a selection is simple, direct and intuitive (Benko, Wilson & Baudisch, 2002). Also, they do not require additional input devices thus they are more robust than free moving input devices such as the mouse (Albinsson & Zhai, 2003).

Apart from these advantages, touch screens suffer from several limitations. First, user's finger (or pen), hand and arm can obscure the screen (Shneiderman, 1991). Second, due to the size of human fingers (or tip of a pen), it is difficult to make a precise selection especially when the target is small (Benko *et al.*, 2002). Third, prolonged use of touch screen can cause arm fatigue (Shneiderman, 1991).

A lot of studies are carried out in order to improve accuracy in selection, reduce error rate, achieve high user satisfaction level and increase performance. In this literature review, experiments on different selection techniques are examined and compared. This review explores how the techniques develop to be more intricate and sophisticated as the supporting hardware advances.

## ISSUES ADDRESSED USING TOUCH SCREENS

Two separate research groups identified that the main drawback in using touch screen is difficulty in selection of small targets. This problem is due to the low resolution of human finger tips (Albinsson & Zhai, 2003). Potter, Weldon and Shneiderman (1988) from University of Maryland and Albinsson and Zhai (2003) from Sweden developed new designs to improve speed, accuracy and user satisfaction.

In Japan, similar research was carried out but with a pen instead of a finger. A stylus (pen) is a much "sharper" pointer than a finger tip, but its resolution is still not as good as a mouse cursor (Ren & Moriya, 2000). Ren and Moriya (1997) identified this problem with pen-based computer and designed a new selection technique.

The problem of selecting small targets can be solved by zooming. Irani, Gutwin and Yang (2006) pointed out that while zooming can provide easy and reliable selection method, it has its shortcoming of losing overview. In most cases, zooming, panning and scrolling can be employed when selecting small targets. However, users are often required to spend considerable amount of time and effort for navigation (Irani *et al.*, 2006). Irani *et al.* developed a new technique called *hop* in order to overcome this limitation.

Recent advances in sensing technology introduced a new generation of tabletop displays that allows multi-touch interaction from several users simultaneously (Wu & Balakrishnan, 2003). Wu and Balakrishnan (2003) pointed out that the current user interfaces do not take advantage of this increased input bandwidth. They presented various multi-finger and whole hand gestural interaction techniques for tabletop displays.

In Canada, similar research was carried out by Buxton and Myers (1986). Because their study took place in 1986, there was no hardware support for multi-touch interaction. They tried to increase bandwidth and degree of parallelism by introducing two-handed input.

Yuan, Liu and Barner (2005) addressed an interesting problem. They identified that current gesture recognition system is based on full hand function and, therefore, is not available for people with physical disability (Yuan *et al.*, 2005). They introduced new gesture designs to overcome this limitation.

## IMPROVING SMALL TARGET SELECTION

In 1988, Potter *et al.* (1988) introduced a selection strategy called *take-off*. *Take-off* was designed to utilize the continuous stream of touch data and give more user feedback. When the finger makes a contact with the touch screen, a cursor (<+>) is shown slightly above the finger to indicate the current position. Until the contact between the finger and the screen is lost, no selection is made. After dragging the cursor, when the user is satisfied with its placement, the selection is confirmed by removing the finger from the touch screen.

*Take-off* scored high marks in lower error rate but it took longer than the normal selection technique. However, the learning curve for *take-off* implied that with more than 15 trials the time differences with other strategies would decrease. Subjective evaluations showed that more intricate strategies with continuous feedback are acceptable to users.

In Japan, similar research was carried out in 1997, but with a pen instead of a finger. Ren and Moriya (1997) introduced a new technique called *space*. *Space* technique highlights the target when the pen is within 1cm high cylinder above the target before the pen lands on the screen. The target is selected at the time of contact for the first time on the screen. They used three techniques; normal selection, *take-off* and *space*; in their experiment.

Contrast to the experiment carried out by Potter *et al.* (1988), the result showed that normal selection strategy performed the best in terms of error rates, selection time and subjective evaluation. My explanation for this result is because a pen has better resolution than finger tip, therefore it is easier to select small targets with a pen. Thus, there is no need for intricate selection strategy. More intricate strategy will take more time to complete and confuse the users when they are not sufficiently trained.

Albinsson and Zhai (2003) carried out an experiment based on two techniques. Their research was focused to design new techniques allowing users to precisely select target at single pixels without resolving to zoom. They compared *zoom-pointing*, *take-off*, *cross-keys* and *precision-handle* in their experiment. *Zoom-pointing* is a familiar concept shown in commercial products such as Adobe Photoshop where the user first activates a zooming mode, then indicates the area to be zoomed in. In *cross-keys*, as shown in Figure 1, the first touch on the screen displays the crosshair with the arrow keys. When adjustments are needed one taps on the handles to move the crosshair in discrete steps. Once on target, the user taps the centre of the circle to make selection.

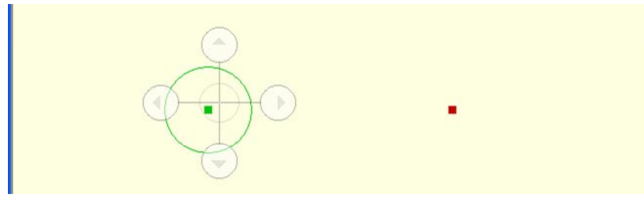


**Figure 1. *Cross-keys* – User taps on arrow keys to make an accurate selection. (Reproduced from Albinsson & Zhai, (2003))**

*Precision-handle* technique consists of a handle, a pivot point and a tip with a crosshair to point the target. As shown in Figure 2, any movement made at the handle is also made at the tip but on a smaller scale, thus increasing precision. (Albinsson & Zhai, 2003)

*Zoom-pointing* performed well showing faster speed with the same error rate and was particularly effective in dealing with small targets. *Take-off* technique performed poorly for small targets but for larger targets (8 pixels), it was faster than any other techniques. *Cross-keys* produced very low error rate with small targets while *precision-handle* performed with satisfactory speed and precision for both small and large targets. In subject evaluation, *precision-handle* was considered to be very close to zoom-pointing in most categories. (Albinsson & Zhai, 2003)

In earlier experiment by Potter *et al.* (1988), *take-off* scored highest marks. However, in 2003, *take-off* performed poorly compared to *zoom-pointing*, *cross-keys* and *precision-handle*. This indicates development of selection techniques between 1988 and 2003, as well as hardware advances that allows design of such new techniques.

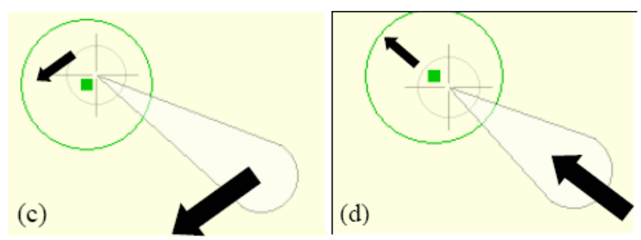
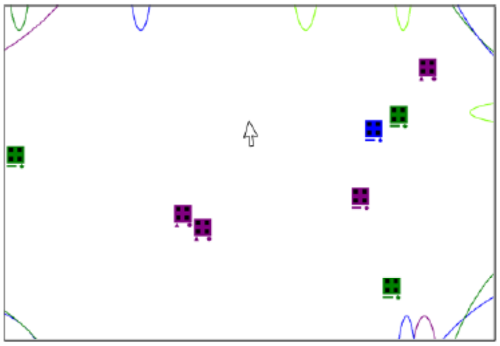


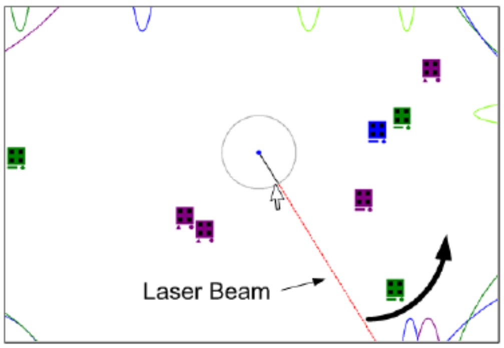

**Figure 2. Precision-Handle – User makes movement as big arrow shows. This is reflected at the tip but on a smaller scale. (Reproduced from Albinsson & Zhai, (2003))**

## OVERCOMING LIMITATION OF ZOOM

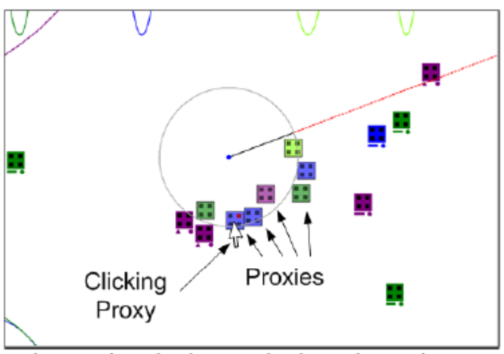
In 2006, Irani *et al.* (2006) introduced a new technique called *hop* (*halo* + *proxy*), to improve selection of off-screen targets. *Hop* uses a combined mechanism of *halo* and *proxy* techniques. Using *hop*, the user can navigate to the target context fast and have awareness of off-screen targets. *Hop* adapts *halo* to provide awareness of off-screen objects. Halos are drawn using oval and circular lines from each off-screen object.



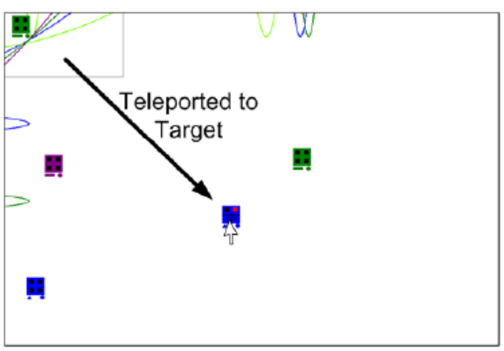
(a) Original View




(b) Laser Beam moving counter-clockwise




(c) Proxies are invoked once the laser beam intersects the halos; user clicks on a proxy




(d) Selecting a proxy teleports the user; final view after teleporting.

**Figure 3. Sequence of actions for a complete hop (Reproduced from Irani *et al.*, (2006))**

As shown in Figure 3, *hop* uses laser beam to start creation of proxies from the off-screen objects. This laser beam is triggered by clicking the mouse on the background and dragging the cursor toward an edge of the middle circle. Then the laser beam rotates counter-clockwise detecting presence of halos. Proxies are created when the laser beam intersects with the halos of each off-screen object. These proxies are brought towards an edge of the middle circle. When a proxy is selected, the user is teleported to the location of that particular proxy.

The experiment involved comparing three different techniques – *hop*, *zoom* and *pan* – against three factors: navigation technique, off-screen distance and density. *Two-level zoom* and a *grab-and-drag panning* techniques were chosen for this experiment as they represent the most common techniques used in current applications. *Hop* performed the best by scoring fastest time in all aspects. Selection times with *zoom* or pan were approximately double of what it was with *hop*. *Hop* showed constant performance regardless of changes in the distance of off-screen objects. Increasing the number of objects and object distance resulted in increase in selection time with the *zooming* interface. As the number of objects increased, performance with *panning* improved.

The results of the study clearly indicates that Irani *et al*. succeeded in developing a new technique that is better at selecting off-screen targets than existing methods. It is interesting to note that they used extensive hardware support such as laser beam and combined two existing mechanism to create a new strategy.

## INCREASING INPUT BANDWIDTH

Tabletop displays could sense multiple points of input with advances in sensing technology in 2003. Wu and Balakrishnan (2003) attempted to take advantage of this increased input bandwidth by presenting numerous multi-finger and whole hand gestural interaction techniques for tabletops.

### Single Finger Techniques

Flickering gesture is used to send an object to another user. As shown in Figure 4(c) when the user taps and drags an object toward the other user past a certain speed threshold, the plan object is "thrown" to the private space of the other user. The opposite gesture is the catching motion (shown in Figure 4(d)). Here, the user touches the surface and draws a straight line in a direction toward him/herself. If the speed of this movement surpasses a certain threshold, the object sitting across the table is copied. The copy of this object sits in the private space of the user.

### Two finger techniques

Two fingers are used to achieve a freeform rotation. The first finger determines the pivot point, while the second determines the rotation angle. While an object is selected, touching a second finger onto the tabletop starts the rotation. The change in angle between the two fingers determines the change in rotation angle for the object as in Dual Touch (Gutwin, 2002).

### Single hand techniques

A user can freely rotate the layout by placing a hand flat on the table (shown in Figure 4(e)) and rotating that hand. As the line between the centre of the hand and the centre of the room rotates, the layout space turns with it. The user can "sweep" objects when the side of a hand is placed on the surface of the table as shown in Figure 4(h). As objects make contact with the hand, they are swept at the same speed as the movement of the hand.

### Two-handed techniques

Sweeping two vertical hands together collects objects in the centre. All the objects move at the same speed as the movement of the hands. As shown in Figure 4(j) two corner-shaped hands are used to create a rectangular editing plane. This plane copies a portion of the shared room layout for individual work. The initial dimensions of the editing plane are defined as soon as the corner-shaped hands are detected. All objects located within this region are copied onto the editing plane, in the same orientations and relative locations as the originals.

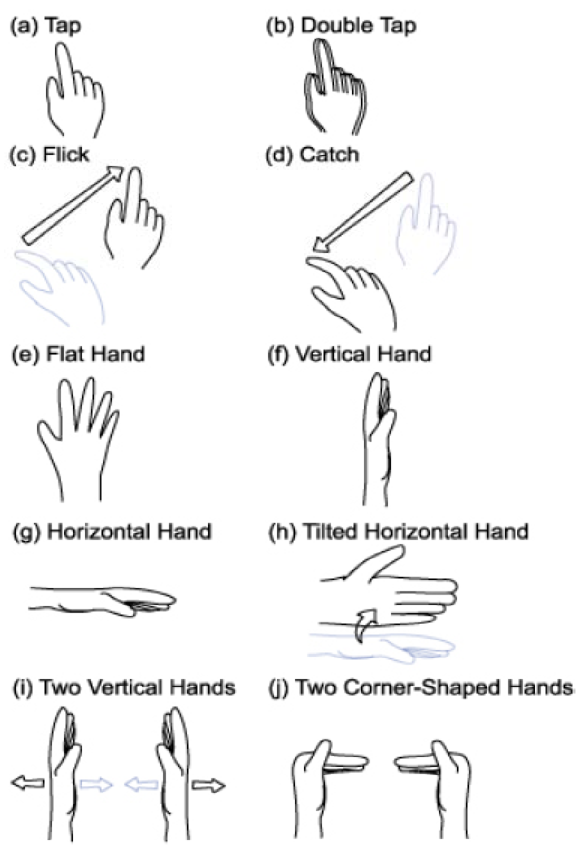



**Figure 4. Gesture set (Reproduced from Wu & Balakrishnan, (2003))**

The observation and experiment showed that the participants required little practice to learn the gesture set and were able to use the gestures effectively. Wu and Balakrishnan (2003) concluded that much research remains to be done before tabletop applications can be reasonably utilized in the real world. They suggested that interesting areas to be explored are further support for awareness, extension to larger sized tables and multi-person collaborative gestural interactions.

Buxton and Myers (1986) also investigated a way to increase input bandwidth. They investigated how two-handed input will affect selection time and user satisfaction. It is important to note that this study took place in 1986 where two-handed interaction was not widely known. Buxton and Myers (1986) performed two experiments. Experiment one consists of performing a compound selection/positioning task. The two sub-tasks were performed by different hands using separate controllers. Experiment two consists of performing a compound navigation/selection task. Comparison between one-handed and two-handed method was studied.

Without prompting, new users adopted strategies that involved performing the two sub-tasks at the same time in experiment one. This can be interpreted that in the appropriate context, users are capable of simultaneously providing continuous data from both hands. The results also indicated that the efficiency of subjects' performance correlates positively to the degree of parallelism employed. More importantly, the experiment demonstrated that such behaviour of using two hands is natural, at least for the task presented. This idea is supported by the subjects' unprompted adoption of two-handed input strategy. For experiment two, the results proved that using two hands for input improved performance for experts and novices. The two-handed input method notably outperformed the common one-handed method. Dissimilar to experiment one, only two participants applied strategies that used both hand simultaneously. The improvement in performance is interpreted as being due to the increased efficiency of hand motion in the two-handed method, rather than two hands being used at once. In the one-handed approach, subjects spent significant time moving the pointer between the document's text and the navigational tools. In the two-handed approach, the hands were always in position for each of the two tasks, thus no time was consumed.

It is interesting to compare different techniques employed to increase input bandwidth in 1986 and 2003. Buxton and Myers (1986) merely utilized two-handed input whereas Wu and Balakrishnan (2003) employed multi-touch and whole hand gestural interactions. This reflects advances in sensing technology between 1986 and 2003.

## FOR PEOPLE WITH DISABILITY

In 2005, Yuan *et al*. (2005) expressed interests in gesture recognition system for disabled people. Currently existing gesture designs involve combination actions of different fingers. This causes difficulty for some users who suffer from partial palm (finger contractures) and pinky side (limited finger and wrist function and range). Motivated by this, they developed single stroke gestures that are more easily performed using partial palm and pinky side. Contact images, consisting of hand trajectory and gesture angles are extracted then fed into a recurrent neural network for recognition.

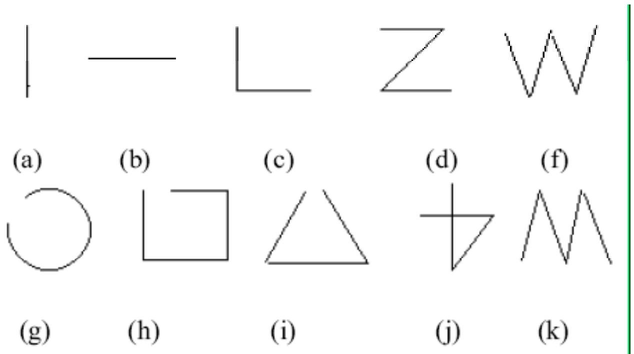



**Figure 5. Examples of single stroke gesture (Reproduced from Yuan *et al*., (2005))**

Figure 5 shows some examples of designed gesture for this experiment. There are two main reasons for using single stroke gesture. Firstly, single stroke gestures can be easily performed by people with partial palm and pinky side and they coincides with a physical process of tensing and releasing the hand. Secondly, using single stroke gesture, there is no need for segmenting of multi-stroke gesture and thus shorter timeout can be used.

In the recognition phase, 10 common tactile gestures such as "down", "rectangle", "triangle", "circle" and "zigzag" were chosen to determine the recognition performances of the system. For each gesture, 100 samples (25 for training set, 75 for testing) were used. The results showed promising recognition rates with an overall correct rate of approximately 94.5%.

This research is very interesting as it sought to extend range of touch screen users. This reflects that "current finger gestures are well designed for users with full finger function." (Yuan *et al*., 2005)

## CONCLUSIONS

After reviewing seven different studies on touch screen, it is evident that selection techniques are becoming more intricate and sophisticated. As early as 1986, Buxton and Myers (1986) sought a way to enable two-handed input. In the experiment of Potter *et al.* (1988), they utilized continuous stream of touch data. Ren and Moriya (1997) were able to input coordinates of the pen-tip before it touches the screen surface. Albinsson and Zhai (2003) introduced more sophisticated methodologies in order to improve accuracy and selection speed. Wu and Balakrishnan (2003) worked to take advantage of advances in sensing technology by increasing input bandwidth. Yuan *et al.* (2005) realized that current gesture recognition system is not suitable for people with disability. Irani *et al.* (2006) developed a sophisticated method to overcome main drawback of zooming, losing overview. This progress in developing new selection strategies is possible because supporting hardware and its drivers are advancing every day.

## FUTURE WORK

A lot of research was carried out regarding touch screens, yet there are more to be done. As indicated by Wu and Balakrishnan (2003), more studies can explore support for awareness, extension to larger sized tables and multi-person collaborative gestural interactions.

Another issue in multi-finger and whole hand gesture recognition arises from the fact that every person has unique hand and finger dimensions and characteristics. Thus, customizable gesture scales could be helpful. This indicates the need for a calibration step or learning on the part of the system in order to determine hand properties for each user (Wu & Balakrishnan, 2003).

As Yuan *et al.* (2005) pointed out there needs to be more designs and techniques in using touch screens for people with disabilities.

Future interfaces should offer a range of tools as there is no single technique that performs well in all circumstances and each user has different preferences. "Well-designed user interfaces should provide a set of tools appropriate to its targeted application and an efficient and clear mechanism to support the selection and switching of these tools." (Albinsson & Zhai, 2003)

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