A Short Report on Multi-Touch User Interfaces

Patrick Lindemann
Department Media Informatics, University of Munich
Amalienstrasse 17
Munich, Germany
patrick.lindemann@campus.lmu.de

ABSTRACT

Recent developments of multi-touch interfaces, which are touch devices able to recognize at least three touches simultaneously, have hit the commercial market with considerable success, as Apple's *iPhone* and *iPad* creations show. The technology is not new, however, but has a long way of more than 30 years of research and development behind it. Considering what the technology is able to accomplish, common applications are still scarce, since apart from a wide range of advantages like flexibility and intuitive interfaces, multi-touch systems also suffer some drawbacks that have yet to be neutralized, which is shown by this report.

Keywords

Multi-touch, multi-person, user interface, touch screen, touch tablet, hand gestures, collaborative systems

1. INTRODUCTION

Nowadays, so-called multi-touch user interfaces are gaining ground, mainly by their distribution in popular smartphones like the *iPhone* by Apple or *Android*-powered phones. As the science-oriented producer *3M Touch Systems* puts it, multi-touch refers to a "touch system's ability to simultaneously detect and resolve a minimum of 3+ touch points" [7]. However, when considering the manifold possibilities such devices offer, there are overall still rather few existing applications of multi-touch technology with relevance for the broad public, making it a paragon topic for recent and current research, which shall be brought closer in the following.

This report provides an overview of the topic of multi-touch devices and related user interfaces. After the motivation and outline of this introduction, the next sections will deal with the history of multi-touch interfaces, introducing some example applications. Next, basic technological knowledge needed for considering such devices shall be mediated before lastly, the major advantages and disadvantages of such interfaces are presented.

2. HISTORY & APPLICATIONS

According to an overview of multi-touch interfaces by Bill Buxton [1] which serves as a basis for this history, the topic started in fact with basic computer keyboards, at least with those supporting the so-called n-key rollover (meaning that more than two keys could be pressed and detected simultaneously), which should put the beginnings of multi-touch roughly somewhere into the early 1970s. Although a first touch screen was introduced in 1972 with the *PLATO IV Touch Screen Terminal*, a multi-touch device did not come up until 1981, when Jack Rebmann produced a *Tactile Array Sensor for Robotics* the usage of which is described by Wolfeld [9] (see figure 1).

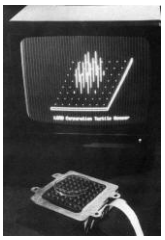

Figure 1: Display showing tactile impression of an object placed on Rebmann's tactile sensor [6]

A set of gestures that Buxton describes as "staggeringly rich" [1] was introduced by Myron W. Krueger in 1983 and resembles the range of gestures still used today, e.g. in Wu and Balakrishnan's *Room Planner* of 2003 [10] which allows for some interior design tasks on a collaborative table. According to Buxton, 1984 brought the first multi-touch screen rather than a mere tablet and together with B. Myers, Buxton himself did "A study in two-handed input" [2] in 1986, examining user interaction on bi-manual tasks that required simultaneous controlling of devices with each hand. Other interesting applications on the way to today's state of research include the *DigitalDesk calculator* of 1991 by P. Wellner [8] which put together real-world paper with a digital projection on a table, as well as an early touch screen phone called *Simon* by IBM & Bell South.

For a whole range of current scientific work on the subject of multi-touch user interfaces as well as from recent years, the device *DiamondTouch* by P. Dietz and D. Leigh [3] serves as a basis. It enables multiple users to simultaneously interact on a touch-sensitive table by independently determining touch locations for each user. An example of a recent appli-

cation built on *DiamondTouch* is the *Collaborative Puzzle Game (CPG)* by Battocchi et al. [4] shown in figure 2.

Figure 2: Cooperative gestures on the *Diamond-Touch*-based *Collaborative Puzzle Game (CPG)* by Battocchi et al. [4]

Recent independent applications with a significantly raised commercial relevance include Apple's *iPhone*, Microsoft's *Surface* interactive table (both 2007) or the N-trig *DuoSense* multi-touch sensor of 2008, which is basically a touch-sensitive transparent frame that can be attached to one's notebook or PC screen and then used as multi-touch device.

3. TECHNOLOGICAL ASPECTS

The following passage shall provide understanding of some basic technologies related to multi-touch interfaces.

3.1 Touch Technologies

There are three major basic technologies for recognizing touches [5], the first being a *resistive* surface which recognizes input by electric currents built between two layers on touch. Second, *capacitive* surfaces using electric fields created from the surface's corners. And lastly, there are *optical* approaches which consist of capturing camera images of a surface and reacting to distinctions created by touches.

3.2 Discrete & Continuous Processing

As Bill Buxton points out, there are two types of actions on touch interfaces [1]. There are discrete input scenarios where users are basically just pushing on specific spots and there are continuous actions where users are performing an ongoing movement that has to be followed. Naturally, the latter requires a more precise touch recognition for reasonable results.

3.3 Information Content of a Touch

Buxton also describes how diverse the information delivered on a single touch can be [1]. Although many systems only react on the position of a touch input, you could also access much further data characterizing the type of the performed touch, including the pressure sensitivity which basically enables a third axis for touch interaction apart from the horizontal and vertical position. Furthermore, the angle in which a finger or device approaches the surface could be recognized, e.g. by the touch contour or by checking where the palm or other fingers are hovering above the surface [10]. Force vectors enable the user to add additional touch data by making use of friction between finger and screen [1].

4. PROS & CONS

This section gives an overview of positive and negative aspects of user interfaces designed for multi-touch systems, mostly based on the observations of Bill Buxton's *Multi-Touch Systems that I Have Known and Loved* [1].

4.1 Advantages

A major advantage of multi-touch systems is the ability to adapt them to almost any imaginable problem that it should solve. As the screen content can be modified to the developer's needs, he can simulate input devices such as keyboards or tasks like technical drawing by creating an adequate virtual reproduction. This makes touch screens a very flexible user interface system and enables extremely intuitive applications, if designed correctly.

Another specific positive aspect of multi-touch lies within the use of simultaneously handled input devices. As users can employ both their hands (and many fingers) or also different devices in combination with their hands at the same time, they are able to make significant improvements regarding the time a task takes to be completed. Users need to be somewhat acquainted with the handling, but on simple and intuitive systems, this seems to be no problem, as Wu and Balakrishnan found out on assessing their *Room Planner* application [10].

Apart from simultaneous usage of hands or devices, you can also extract a lot of information out of a single means of input, as has already been indicated in section 3.3. Finger touches can be varied in pressure sensitivity and angle (on several axes) and hands can be used to express a variety of gestures by tilting, flicking and catching or forming any conceivable kind of sign [10] (see figure 3).

Furthermore, multi-touch opens a whole new set of possibilities for applications since multi-touch implies not only multiple hands or devices but also multiple persons. This enables the creation of reasonable collaborative touch systems, in which several users can interact with the screen as well as with each other simultaneously.

4.2 Disadvantages

On the negative side, multi-touch systems complicate the occlusion problem, as several fingers, hands or devices are clouding even more parts of the touch screen than on single-touch devices. This can, however, be eased by using clever interface design approaches, as Wu and Balakrishnan confirmed [10]. Another basic issue is the fat finger problem which requires designers to use interaction elements of a certain minimum size, in order to be precisely touchable by human fingers.

As multi-touch systems mostly rely on touch screens rather than touch tablets without display, you always need to be able to look at the surface and get discernable display information [1]. However, this is on some occasions hardly possible, like driving a car or operating a device within a pocket. It also restricts simple touch screens from being a beneficial device for visually impaired users. In some fields, a touch screen is mostly exposed to sunlight as with notebooks or mobile phones and visibility can be heavily affected as well.

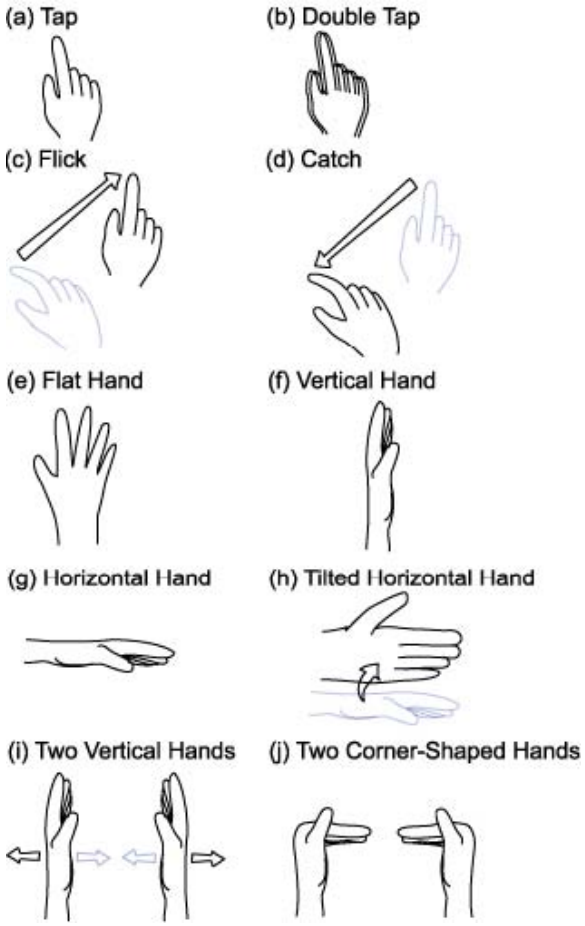

Figure 3: The set of hand gestures supported in Wu and Balakrishnan's *Room Planner* [10]

What is more, some actions like scribbling notes or making finer drawings can not be reasonably performed with fingers and on small screens [1]. You need a device of a certain size that explicitly can handle appropriate input tools such as a stylus additionally to the usual hand and finger recognition. Also, even though touch screens can adapt very closely to a vast number of application purposes, they will only ever be a virtual representation of the original situation and lack certain features such as a plastic shape. This can make a significant difference in the handling of the interface, as can be seen when trying to rapidly handle a virtual keyboard in contrast to the real thing.

5. CONCLUSIONS

In this report, the topic of multi-touch user interfaces was introduced. The history of multi-touch devices was outlined and some milestone applications were presented. Basic technology issues were explained and positive as well as negative aspects of multi-touch interfaces were shown. As can be seen, a lot of diverse research has been done on the subject for quite a long time, and is continuing to take place. This is due to the fact that multi-touch user interfaces are still somewhat scarce on the commercial sector, even though they provide a whole range of interesting opportunities for many conceivable areas of application. This report has hopefully given an inkling of what staggering developments could be expected in the future and how remaining drawbacks of multi-touch devices could be eliminated.

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