Text entry on mobile devices (e.g., phones and PDAs) has been a research challenge since devices shrunk below laptop size: mobile devices are simply too small to have a traditional full-size keyboard. There has been a profusion of research into text-entry techniques for smaller keyboards and stylus input: some of which have become mainstream, while others have not lived up to early expectations. This chapter will review the range of input techniques, together with evaluations, that have taken place to assess their validity: from theoretical modelling through to formal usability experiments. Finally, the chapter will discuss criteria for acceptance of new techniques, and how market perceptions can overrule laboratory successes.

Although phones have traditionally been used for voice calls, with no need for text entry, many services such as text messaging, instant messaging, e-mail and diary operations require users to be able to enter text on phones; text messaging has even overtaken voice calling as the dominant use of mobile phones for many users. Phones and palmtop computers (or electronic organisers/personal digital assistants, PDAs) are too small for a standard desktop or laptop keyboard, thus requiring miniaturisation of the input methods. Furthermore, handheld screen technologies are making it increasingly convenient to read complex messages or documents on handhelds, and cellular data network speeds are now often in excess of traditional wired modems and considerably higher in wi-fi hotspots. These technological developments are leading to increased pressure from users to be able to author complex messages and small documents on their handhelds. Researchers in academia and industry have been working since the emergence of handheld technologies for new text-entry methods that are small and fast but easy-to-use, particularly for novice users. This chapter will look at different
Text Entry

approaches to keyboards, different approaches to stylus-based entry, and how these approaches have been evaluated to establish which techniques are actually faster or less error prone. The focus of the chapter is both to give a perspective on the breadth of research in text entry, and also to look at how researchers have evaluated their work. Finally, we will look at perceived future directions, attempting to learn from the successes and failures of text-entry research.

KEYBOARDS

The simplest and most common form of text entry on small devices, as with large devices, is a keyboard. Several small keyboard layouts have been researched that try to balance small size of overall device against usability. These approaches can be categorized as unambiguous, where one key-press unambiguously relates to one character, or ambiguous, where each key is related to many letters (e.g., the standard 12-key phone pad layout where, say, 2 is mapped to ABC). Ambiguous keyboards rely on a disambiguation method that can be manually driven by the user or semiautomatic with software support and user correction. This section looks first at unambiguous mobile keyboard designs, then at ambiguous designs and, finally, discusses approaches to disambiguation for ambiguous keyboards.

Unambiguous Keyboards

Small physical keyboards have been used in mobile devices from their very early days on devices such as the Psion Organiser in 1984 and the Sharp Wizard in 1989, and have seen a recent resurgence in devices targeting e-mail users, such as most of RIM's Blackberry range. While early devices tended to have an alphabetic layout, the standard desktop layout was soon adopted (e.g., QWERTY for English language countries, French AZERTY, German QWERTZ, and Italian QZERTY layouts – to reduce ambiguity we will, casually, refer to this family of keyboards as QWERTY keyboards). When well designed, small QWERTY keyboards can make text entry fast by giving the users good physical targets and feedback. However, there is a strong design trade-off between keys being large enough for fast, easy typing and overall device size, with large-fingered users often finding the keys simply too small to tap individually at speed. Physical keyboards also interact poorly with touch screens, where one hand often needs to hold a stylus, and they reduce the space available on the device for the screen.

The QWERTY keyboard layout was designed as a compromise between speed and physical characteristics of traditional manual typewriters: the layout separates commonly occurring pairs of letters to avoid head clashes on manual typewriters, and is imbalanced between left and right hands. Clearly, head clashes and manual carriage returns are not an issue with desktops nor handhelds, but their history in the design leads to a suboptimal layout, where users have to move their fingers more often than they would on an ideal layout. Faster keyboards have been designed, the most widely known being the Dvorak keyboard (or American Simplified Keyboard) for touch typists of English-language documents (Figure 1). While significantly faster than QWERTY keyboards, these have not been widely adopted, primarily because of the learning time and invested skill set in QWERTY keyboards. This investment has been shown to carry over into smaller devices, where the suboptimality issue is even stronger, as users tend to type with one or two thumbs, not the nine fingers envisaged of touch typists. There is strong evidence that alphabetic layouts on desktop computers give no benefits even for novice users, and hinder people with any exposure to the QWERTY layout (Norman, 2002; Norman & Fisher, 1982). It can be reasonably assumed this is also true of palmtops, although some research has shown that experience of using a desktop QWERTY keyboard gives no benefit when moved to a very new environment (McCaul & Sutherland, 2004). While optimal layouts could be designed around two-thumb entry, these are likely to be so different from users' experiences that initial use would be very slow and, as with the Dvorak, rejected by end users. Furthermore, these would
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