1 CHAPTER Historical Overview of Consumer Text Entry Technologies

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1.1 INTRODUCTION

Text entry is much more than a feature in modern computers. Textual information and communication are essential parts of our lives. In fact, the wide variety of culture that we can see today is enabled by textual communication. The invention of writing accelerated cultural development, because individuals could store their ideas for later use and for use also by the following generations. Writing is the most specific and flexible way to store information. It has also allowed communication of information or emotions, even over long distances.

Writing systems have been around for several millennia. Writing, as we know it today, is believed to have been developed by the Sumerians in the late 4th millennium BC[1]. From those days, writing media have developed—through stone and clay, to papyrus and parchment, and even later to paper (around 100 AD; Meyer, 1995)—but for a long time writing was done by hand. Handwriting served the cultural needs of storing and communicating information and emotions very well for a long time. Even after the first text-production machine, the *printing press*, was modernized by Johannes Gutenberg in the 15th century, individual citizens still stuck to handwriting, because it met their needs adequately. Even the first "consumer text entry technology," the typewriter, which was invented in 1714, was taken into use only 160 years later, probably because there was not an actual need for such device before then.

Industrialization in the late 19th century changed the situation completely. The new order created a need to produce text in greater quantities. Since then, the amount of written information has increased continuously. The real information explosion, however, began even later, with the birth of the *Information Age* in the

[1] Simpler so-called "proto-writing" systems have existed even longer, probably from as early as the 8th millennium BC.

1980s. The final culmination of textual information is obviously the *Internet.* We are living in a world of text. Although the Internet is increasingly multimodal, the majority of the information within it is textual. The Internet provides an exceptionally powerful medium to share and communicate ideas and aspirations.

The Information Age has also created completely new types of devices. Personal computers started to gain ground in the 1980s and are now ubiquitous. More recently, *mobile computing* has emerged. Although most computing is still done using desktop computers, the vision of "a computer in every pocket" is slowly becoming a reality. One driving need is again communication. Mobility creates new impulses and needs for communication. While some communication remains to be handled through speech, text is better suited for *asynchronous communication.* The growth of text entry will continue, even at an accelerating pace. More and more of the text is being produced in less than ideal mobile settings, which creates new challenges for the creators of text entry systems.

In this chapter, we provide a historical overview of the developments of commercial text entry systems. Therefore, we will leave out many emerging methods that have not yet broken through in the market. Some of these are handled briefly at the end of this chapter, and many potential future technologies are covered in the later chapters of this book.

Our focus is on consumer devices, so professional systems that require long training (e.g., stenograms, Morse code) are left out. We will concentrate on devices for which text entry has an important role. We go through *four device categories* in rough chronological order: (1) typewriter, (2) personal computer, (3) mobile phone, and (4) handheld computers (smart phones and personal digital assistants (PDAs) are discussed together with handheld computers, since although they have different origins their interaction techniques and features clearly approach one another and the different terms are effectively synonyms nowadays).

Interaction techniques within the four device categories tend to be quite consistent, so it is often easy to name one or a few *dominant* text entry solutions for each device. However, as text entry is a very complex problem, even the dominant methods are hardly perfect. Therefore, for each device, numerous *alternative* text entry methods have been proposed. We go through each device category by presenting the dominant solutions first and then proceed to the proposed alternatives. However, due to space limitations, only the most salient solutions will be covered. This includes those solutions that have been particularly successful or novel.

1.2 TYPEWRITER, 1870s TO 1980s

The first commercially successful typewriter was the "Sholes–Glidden Type Writer" produced by E. Remington and Sons beginning in 1874[2]. Figure 1.1 shows this

[2] According to Yamada (1980) the first machine was manufactured in the previous year, but 1874 was the year when the Sholes–Glidden was first placed on the market.

FIGURE 1.1 Sholes–Glidden typewriter.

machine. Its keyboard has a striking similarity to the current computer keyboard layout. (We come back to this point later.) This typewriter was developed by Latham Sholes, Carlos Glidden, and Samuel W. Soule. The main inventor, Latham Sholes, was later referred to as the "father" of the typewriter, but the Sholes–Glidden machine was actually not the first commercially sold typewriter. The "Writing Ball" made by Malling Hansen had been on the market since 1870, although it met with little success. Sholes was not the first typewriter inventor, either. (Actually, he was the 52nd inventor of a typewriter!) The first typewriter is believed to have been invented by Henrik Mill as early as 1714! But most of these early keyboard inventions were not put into practice, or if they were, they were not commercially successful (Yamada, 1980).

One reason that made the Remington line of machines—starting from the first Sholes–Glidden version—a success, was that the time was simply right for a new text entry method. The late 19th century was an era of strong industrialization. Small companies were turning into large corporations, which created a need for improved communication. Also other inventions appeared at the same time, for example, the electric light, telegraph, and telephone. These inventions helped to fulfill the need for increased communication. The typewriter fit very well into the equation, and it is no surprise that the ability to create unambiguous documents with speed was well received in such a booming business environment. By the end of the 1880s the typewriter's monotonous click could be heard "in almost every well-regarded business establishment in the country [USA]" (*Penman's Art Journal*, 1887, according to Yamada, 1980).

Although the typewriter did very well in the business sector, its takeoff in the consumer market was much slower. Typewriters appeared in a culture with a strong tradition of handwritten communication. In the beginning, replying to a handwritten letter with a typewritten response could be considered an insult, because it could be interpreted as a "slander cast on the reader's ability to read longhand" (Yamada, 1980, p. 177). However, typewriters were also purchased by individual consumers. Exact numbers sold to consumers are unknown, but from the early 20th century the typewriter could be considered to have become also a consumer device[3].

During the 20th century typewriters evolved rapidly. Most improvements were mechanical and, later, electronic. Many of these improvements made typing more efficient and ergonomic. By the end of the typewriter era, in the 1980s, typewriters had acquired many features, making them almost like simple computers. Finally, with the success of personal computers in the 1980s, typewriters were phased out by computers due to their more advanced features and more versatile use.

1.2.1 The Dominant Text Entry Method for the Typewriter: The Qwerty Keyboard

As mentioned before, even the first successful typewriter had a keyboard very similar to that of current computers. The arrangement of the alphabetic keys was already following the present-day so-familiar Qwerty layout, with only minor differences. The Qwerty name comes from the first six letters of the top alphabetic key row. The layout was invented by Sholes. Contrary to common belief, the layout itself was never patented. Sholes and his colleagues have several patents, but they are mainly on the keyboard mechanisms (e.g., Sholes *et al.*, 1868). The Qwerty layout was later copied by Remington for the successors to the first Sholes–Glidden model, as well as by many other typewriter manufacturers.

The reasons Sholes came up with the Qwerty layout are quite far from the today's user-centric design principles. The character locations were chosen mainly to overcome the mechanical limitations of the early machines. As anyone who has used an old typewriter knows, the successively actuated levers got jammed easily with one another. Sholes arranged the typebars so that some frequent digrams in the English language were located far away from each other in the typebar arrangement. The mechanical problems of the early machines would soon be overcome, but the later improvements

[3] The number of typewriters sold to individual customers was, however, very small compared to the number of personal computers on today's consumer market.

on the layout were limited to a few letters only. The exact date of the first Qwerty layout identical to today's computer is not known, but it was at least "well before 1887" (Yamada, 1980). Thus, the alphabetic key layout has remained unchanged for over 100 years[4]! The position "monopoly" was finally sealed when the American Standards Institute adopted Qwerty as the standard in 1971.

1.2.2 Alternative Text Entry Methods for the Typewriter

Despite the nearly monopolized position that Qwerty—and its language-specific variations—enjoys nowadays, there have always been competitors, even in the beginning. From today's position of a single standardized layout, the early decades of typewriters seem like a jungle with wide variety of species, in which only a few could survive.

Index Typewriters

In the early decades of typewriters, many of the machines used a text entry method that competed with the keyboard. These so-called *index typewriters* had just a single key (Fig. 1.2). Letters were highlighted by, for example, turning a wheel and then selected with the selection key (Yamada, 1980).

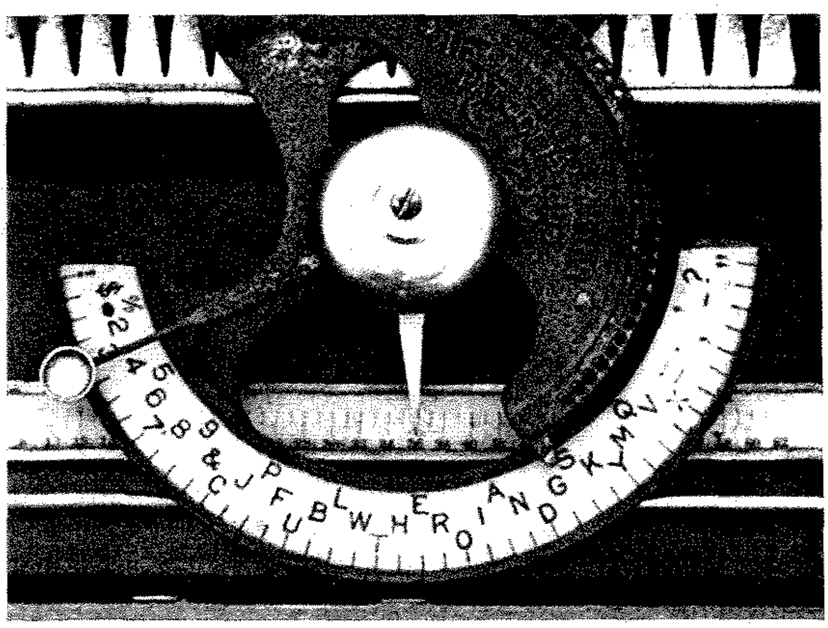

FIGURE 1.2 "World 1" index typewriter.

[4] Some language-specific variations have appeared, though, such as the French Azerty and the German Qwertzu. However, these layouts are very similar to Qwerty, with only a few changed letter positions.

Index typewriters were actually more successful than the keyboarded machines in the beginning, first because the typing method was very straightforward and easy to learn and second due to their simpler structure and lower price. Dozens of different models were produced from the late 19th century to the early 20th century. The Virtual Typewriter Museum gives a very good overview of these models (http://www.typewritermuseum.org/collection/indexi.html).

Ease of learning was probably the main success factor of the index machines, but for the expert users, the keyboarded machines were clearly faster. *Touch-typing* was developed in the 1880s, and during the early 20th century more and more schools started teaching this technique. The speed of touch-typing was so superior that the sales of index machines started to decline, and by 1930s they had disappeared completely.

Double Keyboards

While index typewriters provided a very different approach, there was also competition within the keyboard machines sector. One dispute was related to the input of upper- and lowercase letters. The original Sholes–Glidden from 1874 could actually enter only capital letters! Shifting of the platen was introduced only in the second generation: the Remington Model 2 typewriter in 1878.

However, the so-called *double keyboards* provided a very different solution (Fig. 1.3). In these machines there were two complete sets of alphabetic keys, one for the lowercase and another for the uppercase characters. The "Calligrapher 2" from 1882 was the first such machine, followed by several successful models during the following decades. As happened with the index keyboards, the growth of touch-typing in the early 20th century was again the turning point. Since double keyboards are not at all

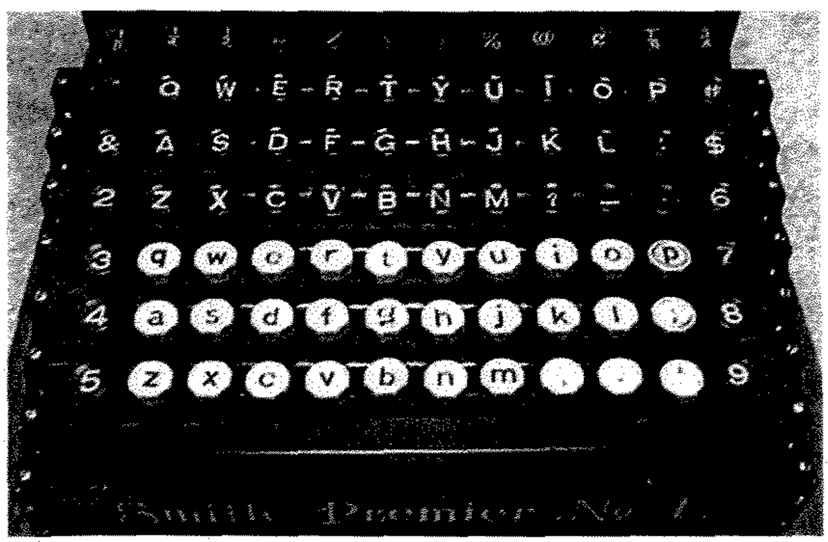

FIGURE 1.3 "Smith Premier 4" double-keyboard typewriter.

optimal for touch-typing, their success gradually waned. By 1922 Smith Premier, the last maker of double keyboards, introduced their first shift-key machine, and the double keyboards disappeared from the market.

Optimized Key Arrangements

As mentioned above, the Qwerty layout was mainly designed to overcome mechanical limitations inherent in typewriters. Keyboard typing is a complex skill, and the physiology of our hands and fingers is not very well suited to such a complex task. This problem became even more acute when touch-typing was introduced. The Qwerty layout was not optimized for human capabilities and limitations, not even for simple 2–4 finger typing, but especially not for touch-typing. There was no chance that Qwerty could have been optimized for touch-typing, since this technique was invented about a decade later than the layout!

With this background, it is not a surprise that a lot of effort has been made to create so-called "ideal" layouts. These layouts, starting with James B. Hammond's layout for the Blickensderfer Portable in 1893, sought to optimize the hand–finger movements. This is accomplished by arranging frequently used letters on one keyboard row and minimizing the load for the weak fingers, such as the ring and little fingers. Several layouts were proposed after the Hammond, especially during the touch-typing success era in the early 20th century. Yamada (1980) gives a good summary of these layouts.

By far the most studied and successful optimized layout is the famous *Dvorak simplified keyboard* designed by August Dvorak and William L. Dealey in 1936 (Fig. 1.4). The Dvorak layout was inspired by extensive research on human motion, and it was designed to be easier to learn, more accurate, faster, and less fatiguing than the Qwerty. The Dvorak layout is also the only optimized keyboard layout that has been thoroughly tested in psychological experiments. Many of these studies have directly compared the Dvorak with the Qwerty layout. However, many of the studies have been criticized of their methods, and despite the decades of testing there is still no consensus about the superiority of the Dvorak layout. For example, the two major summaries of Dvorak's research either declare the Qwerty an "error" (Yamada, 1980) or pronounce the Dvorak's superiority a "fable" (Liebowitz & Margolis, 1990).

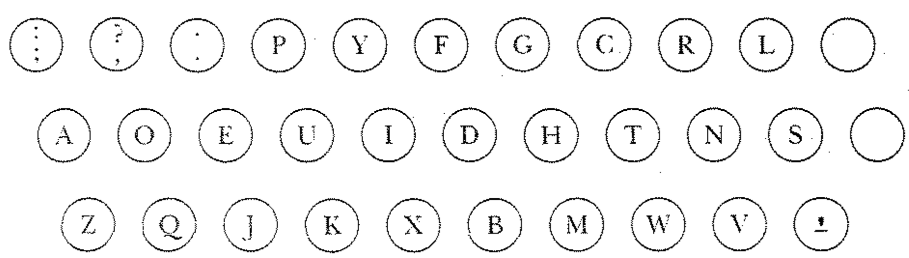

FIGURE 1.4 The Dvorak layout (Dvorak & Dealey, 1936).

Settling a decades-long dispute is obviously beyond the scope of this book, but considering the conflicting research, at least two things can be said with relatively high confidence. First, given enough training the Dvorak layout probably becomes somewhat faster than the Qwerty. Unfortunately, we cannot say how much faster exactly, but 10–20% could be a rough estimate based on the past studies. Second, we can say that achieving the faster speed will take a relatively long time. Fast typing is an extremely complex skill, comparable to playing a musical instrument, and for a person who already knows the Qwerty layout, even reaching the Qwerty speed with Dvorak (or any new layout) will take a considerable amount of time.

A Ph.D. thesis study by B.J. Lessley in 1978 (referred to in Yamada, 1980) gives us an estimate of these two points. In this study, 100 hours of retraining of operators to the Dvorak layout resulted in a learning curve in which the final Dvorak typing speed was 97.6% of the pre-retraining Qwerty speed. The asymptote of the learning curve indicated that the eventual Dvorak speed would become about 17% faster than Qwerty. (There was no control group for retraining to Qwerty, though.)

So, we can predict that Dvorak could indeed be somewhat faster than Qwerty. However, the Dvorak layout has never become a commercial success, although it still has a small but loyal user base. This layout switching problem could be a classical example of Carroll and Rosson's (1987) *Production Paradox*, in which people are willing to learn new things, especially if they are useful, but they also "need to get something done," so they often do not have extra time to spend on intensive training. People *want* to learn better keyboard layouts, since Qwerty is indisputably suboptimal, but they *cannot* learn them, because they do not have the 100+ hours required to adjust to the new layout. Perhaps if the gain in typing speed were clearly better than 10–20%, there would be more Dvorak users, but in the current standing, Qwerty seems to be "good enough" for the majority of users.

1.3 PERSONAL COMPUTER, 1980s TO PRESENT

As mentioned before, personal computers rapidly replaced typewriters thanks to their more advanced features. While typewriters were single-purpose devices, personal computers are multipurpose devices that can do everything that a typewriter can do and much more. So, as soon as computers became affordable, it was only natural that they should replace typewriters.

1.3.1 The Dominant Text Entry Method for the Computer: (Still) the Qwerty Keyboard

Although personal computers are clearly more advanced than typewriters in many respects, the text entry method was simply copied from the typewriter. This was a natural path, since, as mentioned previously, the late electronic typewriters had already evolved into simple computers. It is difficult even to draw a line marking when typewriters changed to computers. Therefore, lacking any clear discontinuity, the text entry method remained unchanged.

Since computer keyboards can be more easily replaced and changed than those in mechanical typewriters, one could expect to see more variation in the keyboard layout. However, the situation is rather to the contrary. The prevalence of Qwerty has been stunning. The variation in keyboards has been limited to the addition of some special keys (for, e.g., Internet browsing or computer games) or some ergonomical optimizations, such as the Microsoft Natural keyboard (Chap. 15). Perhaps another reason for the lack of variation, in addition to the Production Paradox mentioned above, could be an *infrastructural* reason. Computers can nowadays be found everywhere, and they are often used by multiple users. Therefore, it is hard to change the keyboard in only some of the computers, while other computers would continue to feature Qwerty layouts. This would lead to situations in which a single user would have to use and remember several layouts during one day. Since keyboarding is a highly overlearned task, like playing a musical instrument, the switching between different keyboard layouts could be very difficult. Continuing with the music analogy, there are a few multi-instrumentalists, but most musicians are fluent in only one instrument.

However, there are also other skills, in addition to the keyboarding skill, that are widely spread. Two of these are institutionalized to a level at which most people learn them early at their lives, and these two are *handwriting* and *speaking*. This leads us to two possible text entry techniques: *handwriting recognition* and *speech-to-text*. The former, although also possible for personal computers, is more common in handheld computers, so we handle handwriting recognition later in Section 1.5. Speech-to-text is handled next, wherein we also introduce a more special solution: chording keyboards. Handwriting recognition and speech-based input are also presented in more detail in Chaps. 6 and 8, respectively.

1.3.2 Alternative Text Entry Methods for the PC

Speech-to-Text

Since most users can speak appreciably faster than they can write, speech recognition has gained significant research interest. Speech recognition in general involves the computer recording the user's speech and interpreting what has been said. More specifically, speech-to-text or *dictation* refers to the transformation of speech to textual content (as opposed to, for example, system commands).

Commercial speech-to-text systems have been available since the early 1990s. The recognition rate has been the main challenge throughout their existence; to maintain accuracy, the early systems could support recognition of *isolated words* only. The current text-to-speech products (such as IBM ViaVoice or Dragon NaturallySpeaking) have evolved to the extent that they accept *continuous speech.* The error correction techniques have also improved drastically.

Error correction is indeed critical in speech-to-text, since much of the speed potential of dictation can be lost to the correction of errors. Although most people can speak clearly over 100 words per minute, several studies have found significantly lower overall text entry speeds. For example, in the Karat *et al.* (1999) study, the overall text transcription speed with text-to-speech remained at 14 words per minute, which was clearly slower than the traditional keyboard–mouse combination (about 33 words per minute).

The speech-to-text speed remains low, especially if users stick to correcting errors through speech. When speech recognition fails, respeaking is often not an effective strategy. Instead, the new research stresses the importance of *multimodal error correction* (e.g., Karat *et al.*, 2000; Suhm *et al.*, 2001), in which erroneously recognized words are corrected by some other input channel, such as keyboard and mouse or pen input. In a study that involved both inexperienced and experienced users (Karat *et al.*, 2000), it was found that while novice users tend to stick to unimodal error correction (respeaking), the experienced users could much more effectively utilize multimodal strategies and could clearly reach higher overall speeds, in the range of about 30 words per minute.

Although the text-to-speech products already include some multimodal error correction features, this will be a critical area in deciding the success or failure of text-to-speech, since highly accurate recognition is not realistic in the near future. In the words of Karat *et al.*, "error rates in the 1–5% range are the best anyone should hope for."

Even if speech-to-text is not yet the fastest technique, it has potential for situations in which hand use is limited (Chap. 8). It can also help users who have some physical impairment (Chap. 15). For example, many keyboard users suffer from cumulative trauma disorders, and speech-to-text could help these users, perhaps not completely replacing the keyboard, but as a supplementary method, allowing the user to recover from the extended keyboard use.

Chording Keyboards

Text-to-speech presented above seeks to replace or supplement the PC keyboard by utilizing a completely new channel, human speech. A very different approach is taken by *chording keyboards,* which keep the channel of a regular keyboard, i.e., the physical operation through hands and fingers, but take the keyboarding skill to a completely new level. The operation of chording keyboards is based on pressing several keys simultaneously. The operation resembles playing chords on a piano, and thus the name chording keyboard[5]. Chording keyboards have generally very few keys,

[5] The terms "chord keyboard" and "chorded keyboard" are also used.

making them potentially interesting for use in mobile devices. They can also be designed to minimize the hand and finger movements, allowing gains in text input speed. A downside is that the complex chording patterns can be difficult to learn and master.

The idea of chording keyboards is not new, and a similar approach was used in a telegraph by Wheatstone and Cooke as early as 1836. The most widespread chording keyboard, the *stenotype* machine used by court reporters, was invented in 1868 and is still in use today.

Chording keyboards have also been designed for use with consumer devices. Some of these are used with two hands and held on a table and thus compete directly with the standard PC keyboard. To our knowledge, none of the two-hand chording keyboards have been successful, probably because they are quite difficult to learn. While even touch-typing is too tedious to learn for many users, the chording patterns are motorically even more demanding. They also pose a cognitive challenge to the user, since unlike regular single keys that can be labeled and searched visually, the chording patterns need to be memorized.

Another category of chording keyboards is used with one hand. These are often designed for mobile handheld usage, for example *wearable* computers. This is a stronger potential spot for chording keyboard adoption, since handheld chording keyboards are not just a replacement for the regular keyboard, but might enable text entry for new types of mobile devices.

The most well-known and most studied one-handed chording keyboard is the *Twiddler* (http://www.handykey.com/). The first version of the Twiddler was made in the late 1980s. Regular characters can be obtained with one-key or two-key combinations. There are also special shortcut chords for frequent words (e.g., "and," "to") and common word endings (e.g., "-ing," "-ed"). Twiddler is held in one hand, with a strap supporting the grip. The 12 main text entry keys are placed on the back side of the device, so the keys cannot be seen without turning the device around. While such usage obviously takes a while to learn, the benefit is in the natural arm and hand position. When using an external display (Twiddler has no internal display), the forearm can be held in a completely extended position. Since the device also fits almost completely inside the hand, typing can be done almost "invisibly." This may be a benefit for mobile and wearable devices, and Twiddler has become the most widely used wearable keyboard to date. Lyons *et al.* (2004) have proposed that Twiddler might also be ideal for use with mobile phones.

Lyons *et al.* (2004) tested Twiddler in a longitudinal learning study with inexperienced users. The typing obviously took a while to learn. The speed started at about 5 words per minute, and after about 6 hours of net practice (20 × 20-min sessions), about 25 words per minute speed was obtained on average.

So far chording keyboards have been adopted only by a few wearable-computer "geeks" and some special mobile professionals, but they might be more successful in the future if wearable computing becomes more commonplace.

1.4 MOBILE PHONES, 1990s TO PRESENT

The telephone was invented in the late 19th century. As with typewriters, there is no consensus on who was the original inventor, but Alexander Graham Bell's name is most often mentioned in this context. The early phones used manual switchboards, and later rotary dials, but the 12-key *number keypad* was introduced as early as the mid-20th century (see especially the legendary studies by R.L. Deininger in 1960).

In the 1980s, the first *mobile phones* appeared (also called *cellular phones*). In the beginning, mobile phones were used very much like landline telephones, that is, mainly for speaking. The user interface was also copied from the predecessor, and most phones use the 12-key keypad even today (Fig. 1.5). However, more recently, mobile phones have gained a myriad of new features. The most advanced models are becoming very similar to handheld computers. These models are discussed in greater detail and grouped with handheld computers in Section 1.5.

Most basic models, addressed here, still incorporate the 12-key keypad, and their use is still very voice-call oriented. However, text-based messaging has become another cornerstone of these devices. Mobile phones entered the era of text messaging when the *Short Message Service* (SMS) emerged in GSM phones in the early 1990s. Very soon, almost all GSM phones incorporated SMS messaging, and nowadays instant messaging, multimedia messaging, and even full-scale e-mail have also become used features of all mobile phones. The GSM Association (2006) estimates that "a worldwide total of 1 trillion" (1,000,000,000,000!) SMS text messages were

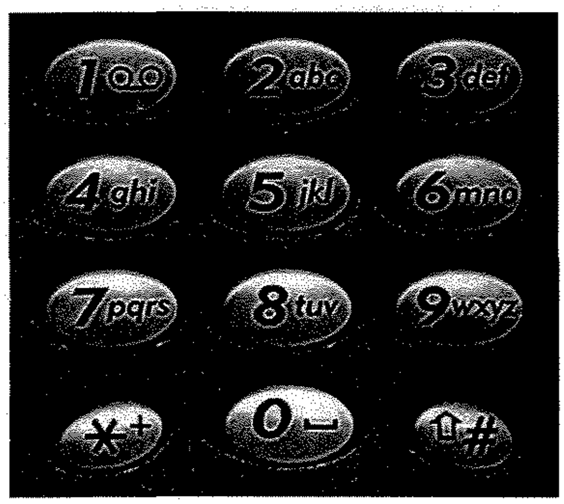

FIGURE 1.5 The 12-key keypad on a mobile phone.

sent during the year 2005. In many markets, text messages have even outnumbered the amount of voice calls. This makes even the basic mobile phone an important text entry device. As such, mobile phones were the first widely successful *mobile* text entry devices. In the mobile context, the text entry systems are facing new challenges, since the users need (and want) to enter text in situations that are more restless and less controlled than the static office environment.

1.4.1 The Dominant Text Entry Methods for Mobile Phones: The 12-Key Keyboard

The 12-key keypad poses a special challenge for text entry, since most languages have at least 26 characters. This leads to an overloading, by which each key contains several characters. Special techniques need to be used to overcome this ambiguity. The two dominant techniques used in mobile phones, both of which can appear in the same device, are multitap and predictive methods.

In the *multitap* method, each key is pressed one or more times to specify which character is wanted. This method obviously increases the number of keystrokes and is therefore quite slow. Typing speed values around 10 words per minute are typical.

In *predictive*[6] methods, a dictionary in the phone's memory is typically used to find the matching words for the key sequence. The most well-known predictive method is probably the T9 by Tegic (www.t9.com; see also Chap. 15), but other similar methods exist as well. In T9, the user makes one key press for each character, and the key sequence for the whole word is matched with the phone's dictionary. If the prediction works well, text can be entered with only about one key press per character. However, the fluency of the typing depends a lot on the match between the user's vocabulary and the phone's dictionary. If the intended word is not in the dictionary, then the user must make an extra effort. Thus, it is not easy to give a single speed estimate for predictive methods. In optimal cases, when all words match with the dictionary, speeds of about 20 words per minute can be easily obtained. In the worst cases, the speed can fall lower than the multitap speed level.

It is obvious from the above that the current phone text entry methods are not very well suited to large-scale text entry. Therefore, several alternative solutions have been created. We present these in the next chapter.

The use of predictive methods is not limited to mobile phones. The study of predictive entry systems began in Japan in the 1960s (see Chap. 11). Although the English systems are limited to a phonetic base, various other predictive entry methods exist in East Asia, for example, the use of shape-based entry systems in Chinese

[6] The predictive methods discussed here are predictive only in the "narrow sense." See the discussion in Chap. 2.

(see Chap. 11). Predictive methods have also opened new possibilities for communication for the disabled (see Chap. 15).

1.4.2 Alternative Text Entry Methods for Mobile Phones

The 12-key mobile phone keypad is such a limiting feature for text entry that some advanced "smart phones," which are designed to support, for example, full-scale e-mail, have completely given up text entry with the 12-key keypad. (These phones might still have this keypad in some form, but it is not used for text entry.) We will discuss these smart phones in the handheld computer section below. Instead, we describe here alternative layouts that keep the numeric 12-key layout but introduce a new layout for the alphabetic characters.

One of the most studied alternative phone layouts is probably the *Fastap* layout (Levy, 2002), formerly known as OneTouch. See Fig. 1.6, left. Fastap has the standard 12 number keys, but character keys A–Z and some punctuation keys are interlaced between these. The character keys are organized in alphabetical order. The whole keyboard is quite small, containing over 40 keys in a space not much larger than a standard phone keypad. On the other hand, all the frequent letters in the English language are available through one key press. This makes the layout potentially quite fast. A study by Sirisena (2002) showed promising results. However, very few mobile phone models have adopted this layout to date (we discuss the slow adoption more below).

Another approach, used in some existing commercial devices (e.g., SonyEricsson M600 and BlackBerry 7100), is to retain the phone keypad number layout and overlap

FIGURE 1.6 Left: Fastap keyboard (www.digitwireless.com). Right: BlackBerry 7100v reduced Qwerty keyboard.

it with a *reduced Qwerty* keyboard. See Fig. 1.6, right. Reduced Qwerty, in this case, refers to the characters being ordered in a typical Qwerty fashion, but the number of keys has been cut down by placing two or more characters in each key. Similar to phone keypad input, multitap and predictive techniques can be used here also, to overcome the ambiguity. The SonyEricsson device uses a new strategy, in which each key can be *tilted* by pressing them down on the left or right side of the key to select one of the two characters. These layouts are interesting, but they are still relatively new, and so far no usability studies of any of the reduced Qwerty layouts have been published.

Both Fastap and the reduced Qwerty layouts are quite new and have not been widely adopted in mobile devices. This may perhaps change in the near future. The situation is reminiscent of the position of the Dvorak layout in the Qwerty-dominated computer world. A new layout can probably succeed only if it can overcome the Production Paradox. That is, the users will probably adopt a new layout only if it fulfills two needs. First, the layout needs to show a clear benefit to the user, e.g., in terms of improved efficiency or comfort of use. And, second, the layout needs to be quite easy to learn. The first point might be hard to estimate for the individual customer; it could perhaps be proven by research, but so far very few studies exist, and they have almost certainly not reached the individual customers. The second point, the ease of learning, might also be difficult to estimate. However, the reduced Qwerty layout might be in a better position in this respect, since the familiar Qwerty layout might make it easier to learn or at least might make it *appear* so.

In the future, mobile phones might become like PCs, with only one dominating text entry method, or we might see more variance. At the moment, the new layouts have existed for such a short time that it is too early to predict their future.

1.5 HANDHELD COMPUTERS

The idea of a powerful handheld computing devices has been around at least since 1968, when Alan Kay envisioned the *Dynabook* concept (Meyer, 1995). It was an idea of a small and light device that could be used to take notes and to interact wirelessly. Obviously, in the late 1960s, the technology was not mature enough to realize the Dynabook. However, its idea encouraged later concepts and prototypes. In 1987, Apple presented a prototype of the *Knowledge Navigator* concept, which in turn evolved to the first commercial handheld computer, the *Newton Message Pad* by Apple.

The first Newton was released in 1993, followed by several advanced devices during the next 5 years. A good summary of the Newton devices can be found in the Apple history site (http://apple-history.com).

The Newtons were highly advanced devices, with lots of visionary features, and they got a relatively small but very loyal base of users. On the downside, the devices were rather heavy, bulky, and expensive, and some of the technologies (e.g., the advanced handwriting recognition) were not yet very mature.

In 1996, a clearly smaller, simpler, and more affordable pen-operated device appeared: the Pilot organizer. Despite its technical inferiority to the Newton, the Pilot seemed to match the users' needs better. The sales of Pilot rose quickly, while Newton's sales declined. In February 1998, Apple officially discontinued the Newton and all related products. Pilot devices still exist and are sold under different names (Pilot, PalmPilot, Palm, HandSpring, etc.). Other operating systems (such as the Windows Pocket PC) and manufacturers have appeared, but all the devices today are still clearly just "simple pen-operated computers," and the advanced thinking found in the Newton has not (yet) reappeared.

Apart from these pen-operated devices, there was another category of devices that used a full Qwerty keyboard. The Psion organizers in particular were popular and advanced devices. They are no longer manufactured, but they have evolved into Symbian devices, such as the Nokia Communicators. Symbian is also used in smart phones, which nowadays cover such a wide range of features that they can also be classified as handheld computers.

1.5.1 Dominant Text Entry Methods for PDAs

Unlike for the previously presented devices, it is hard to name any single dominant text entry method for handheld computers. Instead, we present three methods: handwriting recognition, virtual keyboard, and physical mini-keyboard.

Handwriting Recognition

In *handwriting recognition* (HWR) the device interprets the user's handwritten characters or words into a format that the computer understands (e.g., Unicode text). The input device typically comprises a stylus and a touch-sensitive screen. There are many levels of HWR, starting from the recognition of simplified individual characters to the recognition of whole words and sentences of cursive handwriting (Chap. 6).

The HWR of Apple's Newton was very advanced. The first Newtons already accepted whole words and even the use of cursive writing. The Newton could also learn the user's writing style and had sophisticated features like the recognition of common shapes and symbols. However, the recognition accuracy was often not very good. Version 2.0 of the Newton operating system introduced a more simplified recognition of printed text, with better recognition accuracy. However, the suboptimal handwriting recognition was unquestionably among the reasons for the Newton's downfall.

In 1993, the same year that the first Apple Newton device was sold, Goldberg and Richardson from Xerox PARC published a paper about a very different approach: *Unistrokes* (Goldberg & Richardson, 1993). In many ways, Unistrokes are the complete opposite of the Newton. While the Newton tried to provide a completely "natural" method of handwritten text entry, and unfortunately failed, the Unistrokes

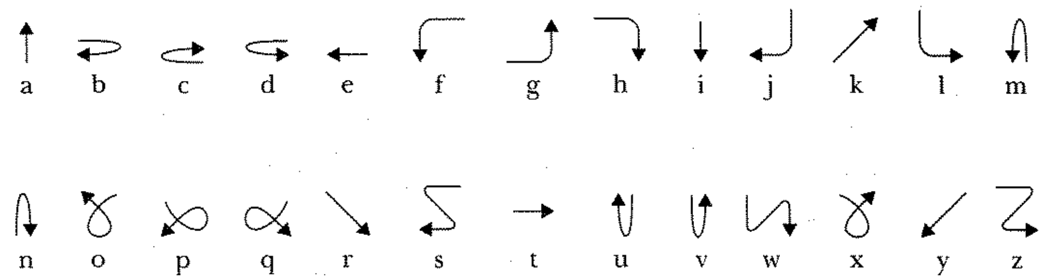

FIGURE 1.7 Unistrokes character set (Goldberg & Richardson, 1993).

technique completely distanced itself from natural usage. Instead of letting the user write freely, Unistrokes sought to optimize the recognition accuracy and text entry speed. Goldberg and Richardson wanted to design a character set that could be entered in an eyes-free manner (they even called their system "touch-typing with a stylus"). To meet these requirements a completely new, highly simplified character set was designed, in which each character could be drawn by a single stroke (thus the name Unistrokes). The downside of Unistrokes is that they require one to learn the character set (Fig. 1.7). Since some characters are quite far from their printed letter counterparts, this might slow down the adoption of the system. Goldberg and Richardson tested their system on users, but unfortunately they did not report the error rates (Goldberg & Richardson, 1993).

The learning problem was eased to some extent when the first Pilot organizer in 1996 introduced *Graffiti*. Graffiti is akin to Unistrokes in that most of its characters can be entered by single stroke, but the Graffiti characters are less "artificial" than the Unistrokes and much closer to printed letters. This naturalness was further developed in later versions of Graffiti and other similar systems, such as the one used in Windows-based Pocket PCs.

Graffiti got a lot of attention during the late 1990s, and it still has its advocates. However, other text entry methods, such as virtual keyboards and small mechanical (Qwerty) keyboards, have become increasingly popular in the recent handheld computers.

Handwriting recognizers are also available for all the main PC operating systems, such as the Tablet PC version of the Microsoft XP and the Inkwell for Mac OS X. The pen-operated PCs are still used mainly by, for example, graphical artists, and their use is driven much more by their drawing features than by text input.

The future of handwriting recognition is difficult to predict, but one scenario, not a very optimistic one, suggests that handwriting skills are starting to degenerate with the increased keyboard use. This trend will probably happen quite slowly though, and handwriting will probably not completely lose its significance, at least not during the next few generations.

Virtual Qwerty Keyboard

Even though the first Newton and Palm devices were clearly marketed and perceived as "handwriting devices," a backup method has been provided in every device: i.e., a *virtual keyboard.* To use the virtual keyboard, the user taps the "virtual keys" on a keyboard image (usually organized in the familiar Qwerty layout). The virtual keyboard serves as a backup method, but it is also used as the primary method by many users who do not want to learn the handwriting recognition or whose handwriting is not very clear.

Virtual keyboards are less prone to errors than handwriting recognition, but a few studies indicate that they might also be faster (e.g., MacKenzie *et al.,* 1994; Költringer & Grechenig, 2004; Luo & John, 2005). Another benefit of virtual keyboards is that they can be easily customized, for example using an optimized layout. We discuss the alternative virtual keyboards later.

Physical Mini-keyboards

As opposed to the virtual keyboard on screen, many recent handheld computers and smart phones also have a tiny mechanical keyboard. The most used layout is again the familiar Qwerty (Fig. 1.8).

While the full-sized PC keyboard is suitable for full 10-finger use, even for touch-typing, the use of the mobile mini-keyboards is mainly limited to two-finger typing. Most users hold the device in two hands and use the two thumbs for typing. Although such thumb typing is obviously clumsier than the full 10-finger typing, a recent study by Clarkson *et al.* (2005) showed that significant speeds can be obtained after very little practice. Even users with limited prior experience can type over 30 words per minute, and the average speed can exceed 60 words per minute (!) after a few hours

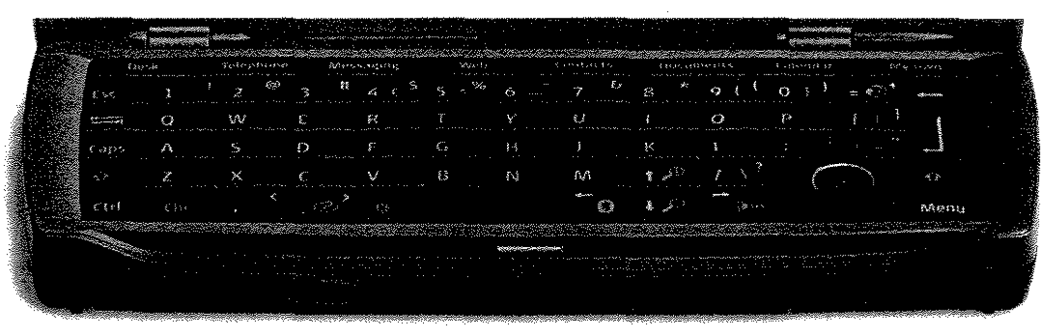

FIGURE 1.8 Qwerty keyboard of the Nokia 9500 Communicator.

of practice. This figure is clearly higher than the about 10–25 words per minute typical with other techniques, so physical mini-keyboards are a strong option for users who value efficiency.

However, the downside of these keyboards, as well as any finger-operated keyboard, is that they may create repetitive strain injuries with extensive use, especially since the thumbs are not as agile as, for example, the index fingers. At the moment, the mini-keyboards and extensive mobile text entry are relatively new phenomena, and so far no studies of ergonomical problems have emerged to our knowledge. However, we might see such problems in the future if the mini-keyboard and mobile e-mail successes continue.

1.5.2 Alternative Text Entry Methods for Handheld Computers

Alternative Virtual Keyboards

Virtual keyboards are presented on the device screen and are therefore easy to change through software. Therefore, it is no surprise that alternative layouts have been proposed also for this category of keyboards. Since the virtual keys are pointed at with a stylus, the alternative layouts typically change the positions of the keys to minimize the time and effort needed for stylus movement. Sometimes also completely new keys are introduced. Since the Space character is very common, many alternative layouts provide more than one Space key.

Some proposed layouts are, for example, *Fitaly* (http://fitaly.com; tested by MacKenzie *et al.*, 1999), *OPTI* (MacKenzie & Zhang, 1999), *Metropolis* (Zhai *et al.*, 2000), and *ATOMIK* (Zhai *et al.*, 2002).

The use of alternative virtual keyboards is based on straightforward pen tapping with one hand. Therefore, their typing speed can be estimated by Fitts' law analysis (Fitts, 1954; see also MacKenzie, 1992). The results indicate that the alternative layouts could indeed increase text entry speed, even as much as about 50% (Zhai *et al.*, 2002)! It should be noted that speed is, however, not the only usability factor, and very few studies with actual users have been carried out.

The user studies by Smith and Zhai (2001) and MacKenzie and Zhang (1999) indicate that the initial typing speed is moderate (around 10–15 words per minute), and it takes about 4 hours net training time to surpass the typing speed of the Qwerty layout. This is a clearly shorter learning time than the over 100 hours found in the Dvorak vs Qwerty typewriter study (Yamada, 1980). However, to our knowledge, none of the alternative virtual keyboards have been very successful so far, although they have been available for several years. We do not know the reasons for this, but perhaps the Qwerty layout is again "good enough" for the users not to invest in the learning of a new layout.

Gesture-Based Input

An interesting direction for the future are gesture-based text entry methods. Since our focus is on commercial text entry, and none of the gesture-based methods have yet been successful, we will handle these only briefly.

Virtual keyboards require constant visual attention. Every character must be entered by hitting exactly within the boundaries of the virtual keys. This makes the use tedious, especially in mobile situations, in which the visual attention is often needed elsewhere. Gesture-based input methods have been created to overcome this problem. Instead of tapping on small keys, gestures are drawn on the screen. Unlike the handwritten characters, which can also be classified as gestures, the gesture-based methods discussed here do not utilize the letters in the alphabet, but are based on other metaphors, such as virtual keyboards or pie menus.

Some gesture-based text entry methods are *T-Cube* (Venolia & Neiberg, 1994), *QuikWriting* (Perlin, 1998), *Cirrin* (Mankoff & Abowd, 1998), *MDITIM* (Isokoski & Raisamo, 2000), and *EdgeWrite* (Wobbrock *et al.*, 2003, 2004).

A recent and interesting gesture-based input concept is *shape writing*. It has been developed through research by Zhai and his colleagues. The original version was called *Shark* (Zhai & Kristensson, 2003), and the later improved versions were *SHARK*^{2} (Kristensson & Zhai, 2004) and finally *ShapeWriter*. These methods have shown potential for high text-entry speed, although they have been tested in one informal trial only (Kristensson & Zhai, 2004). The average speed in this informal study was about 70 words per minute! The results need to be verified in more formal experiments using more subjects, but shape writing is a promising text entry concept for future mobile devices. ShapeWriter is handled in more detail in Chap. 7 of this book.

1.6 CONCLUSIONS

We have gone through four cornerstone devices in the text entry arena: typewriter, personal computer, mobile phone, and handheld computer. While text entry methods within each of these four devices are very consistent, the intradevice differences are very clear. While the typewriter and its successor, the personal computer, have been operated mainly through the keyboard, the newer devices use also different techniques. This suggests that despite the apparent conservatism within existing devices, the emergence of radically new device forms creates *discontinuity points* that give ground to new text methods.

The continuing trend of mobilization and device miniaturization will potentially create such discontinuity points. We are still in the early phases of the mobile device era, and while the clear majority of the current mobile devices can be classified as *handheld*, the future mobile use could be very different: *wearable, ubiquitous, implanted*—even some that have yet to be named or even conceived.

Although the Qwerty keyboard has served us well since 1874, we are better prepared for the future by studying new, radically different text entry methods for future device forms.

1.7 FURTHER READING

Due to space limitations, this chapter was able merely to scratch the surface of text entry history. Fortunately, good sources exist, both online and in printing. Meyer (1995) gives a thorough overview of pen computing technologies, including pen-based text entry. This paper also gives a summary of the early history of writing.

The history of typewriters and keyboards is pretty well documented. The history of typewriters is thoroughly analyzed by Yamada (1980). The Virtual Typewriter Museum gives a good overview of the early typewriters with lots of pictures and a nice time line (http://www.typewritermuseum.org/). Numerous alternative keyboards are listed in the Typing Injury FAQ site (http://www.tifaq.com/keyboards.html).

A more general history of human–computer interaction is given by Myers (1998).

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