An Answer to "Who Needs a Stylus?" on Handwriting Recognition on Mobile Devices

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Abstract. "Who needs a stylus?" asked the late Steve Jobs during his introduction of the iPhone. Interestingly, just at this time, Apple had made a patent application in handwriting and input recognition via pen, and Google and Nokia followed. So, "who needs a stylus then?" According to our experience in projects with mobile devices in the "real-world" we noticed that handwriting is still an issue, e.g. in the medical domain. Medical professionals are very accustomed to use a pen, whereas touch devices are rather used by non-medical professionals and definitely preferred by elderly people. During our projects on mobile devices, we noticed that both handwriting and touch has certain advantages and disadvantages, but that both are of equal importance. So to concretely answer "Who needs a stylus?" we can answer: Medical professionals for example. And this is definitely a large group of users.

Keywords: Handwriting recognition, Pen-based input, Mobile computer, Human-computer interaction.

1 Introduction

The late Steve Jobs argued in 2007 "Who need a stylus?", interestingly Apple has made a patent application on it [1], which was already in the mind for the Apple Newton [2].

Undoubtedly, it is true that touch input is well accepted and easy to learn, even amongst non-computer literate people and elderly people [3, 4]. Devices with touchscreens are useful in hospitals, where patients can, for example, fill out questionnaires while they are waiting for their examination, for the reception by the doctor, or during other spare times [5]. Direct input of questionnaire answers by the patients makes the error prone and time consuming copying of completed paper sheets unnecessary. This saves time, which can be used for direct contact with the patient, thereby improving the overall quality of the interaction between doctors and

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their patients. Although touch is a very intuitive way of interaction, it was shown that in a professional medical context, styluses are preferred over finger-based input [6].

Input via stylus has the advantage of being more precise and the action is similar to the user's accustomed writing on sheets of paper – and paper is still a preferred medium in the hospital [7]. For addressing the problem of imprecise touch, using fingers, Vogel & Baudisch [8] developed a system called Shift, which makes it possible to make more precise selections using a finger. Shift shows a copy of the touched screen location and shows a pointer representing the selection point of the finger if the finger is placed over a small target. However, for further improving the precision of touch input via finger it must be better understood how people touch touchscreens [9].

Another problem with touch input using fingers is that the user's "fat fingers" also cover the areas the user intends to touch. To circumvent this problem [10] developed a mobile device which can be operated from the back. In addition, by using back-of-device interaction, it is possible to create very small touch devices [11].

Despite all these facts, medical professionals (medical doctors, nurses, therapists, first responders etc.) are more familiar with dictation and handling a stylus, since they are used to handling a pen all the time [6], [12], despite the issue of poor handwriting in medicine generally [13].

Let us take a short look at the mobile market: Worldwide sales of mobile devices totaled 440.5 million units in the third quarter of 2011, up 5.6 percent from the same period last year, according to Gartner, Inc. Smartphone sales to end users reached 115 million units in the third quarter of 2011, up 42 percent from the third quarter of 2010 and accounted to accounted for 26 percent of all mobile phone sales. In the third quarter of 2011, Android OS accounted 52.5% of worldwide smartphone sales to end users (compared to 25.3% a year earlier) whereas Symbian accounted for 16.9% (36.3% a year earlier), iOS accounted 15.0% (16.6 a year earlier) and Research In Motion accounted 11.0% (15.4% a year earlier) according to Gartner [14]. The majority of smartphones are tailored toward the business-to-consumer (B2C) market, thus the predominant input technique for mobile devices is the multi-touch concept (Wang & Ren, 2009). The majority of smartphones are tailored toward the business-to-consumer (B2C) market, thus the predominant input technique for mobile devices is the multi-touch concept [15].

Moreover, a press release from IDC in September 2011 stated: *By 2015, more U.S. Internet users will access the Internet through mobile devices than through PCs or other wireline devices. As smartphones begin to outsell simpler feature phones, and as media tablet sales explode, the number of mobile Internet users will grow by a compound annual growth rate (CAGR) of 16.6% between 2010 and 2015.*

As regards input technology, the most recent development on the mobile market is at contrast to the preferred input technique of professionals in the medical domain. Whereas, from the view-point of Human-Computer Interaction (HCI), handwriting can be seen as a very natural input technology [16], studies have shown that a recognition rate below 97% is not acceptable to end users [17]. The challenge in developing such a system is the fact that the art of handwriting is very individual for everybody, making a universal recognition of all handwriting particularly demanding [18].

A typical example is the case of incoming patients in the triage (aka EBA: first clinical examination),, where it is similar to an emergency: Rapid patient information collection is crucial. Promptly and accurately recorded and well communicated vital patient data can make the difference between life and death [19], [20]. Consequently, the data acquisition should have as little disruptive effect on the workflow of the medical professionals as possible. In the past, solutions for data input on mobile applications have been tested in the field [21], [16], [22], [23], [6], [18], [24].

Due to the fact that emergencies are usually complicated by difficult physical situations, special attention has to be given to the design of information technology for emergencies [25]. A key issue of any such information system is the acquisition of textual information. However, extensive text entry on mobile devices is principally to be avoided and a simple and easy to use interface, in accordance with the maxim: *less is more*, is a supreme necessity [23].

The basic evidence is that entering data onto a mobile device via a stylus is slower, more erroneous and less satisfactory for end users than entering data via a QWERTZ (de) or QUERTY (us) keyboard, as has been demonstrated in some studies [26], [27], however, the use of a stylus is much faster and more accurate than using finger touch [6].

2 State-of-the-Art in Handwriting Recognition Methodologies

Handwriting recognition is still considered an open research problem, mainly due to the substantial individual variation in appearance, consequently the challenges include the distortion of handwritten characters, since different people may use different style of handwriting, direction etc. [28].

If a system needs to deal with the input of different end users, a training phase is required to enable the system to understand the user's art of writing. The data received in this phase is stored in a database. During the recognition process, the system compares the input with the stored data and calculates the output.

Basically, handwriting recognition can be separated into online and offline recognition.

I) Offline Handwriting Recognition. Offline recognizers have not received the same attention as online recognizers [29].

There are several problem areas (e.g. postal address recognition) where offline handwriting recognizers are very useful due to the large amount of hand written text.

These systems have the ability to convert text into image form. The main disadvantage is that there is no possibility of obtaining information about the type of the input.

First, the text has to be separated into characters or words. With Hidden Markov Models or Neural Networks these words are matched to a sequence of data [30]. Most recently a work based on hybrid statistical features has been published [31].

II) Online Handwriting Recognition. These systems collect data during the process of input. The advantage is that specific information, such as the number of used strokes, can be collected. The result is calculated in real time [32].

This kind of recognition is used mostly in communication devices, such as Smartphones or PDAs. In this paper, we concentrate on the online handwriting recognition technique [33] and present a detailed review of techniques and applications for online cursive handwriting recognition.

The first part of this article deals with the review of the main approaches employed in character recognition, since most of these are also used in cursive character recognition.

III) Recognition Process. Most recognition systems comprise of four distinct recognition phases [32]:

(1) Preprocessing: In this step, noise and other undesirable effects are reduced to improve the data for the recognition process [32]. Typically, some form of noise reduction and size normalization is applied.

Noise Reduction: During the input, undesired data can also be registered. For example, if the user accidently touches the screen. Such "wild points" have to be corrected.

Size Normalization: During the input the size of a character can vary. For a better recognition the characters have to be normalized to a general size.

(2) Feature Extraction: In this step, the relevant information from the input is extracted. The challenge is to extract a minimal set with maximum data recognition.

(3) Classification and (4) Recognition: The goal is to find the optimal letter to a given sequence of observations. The letter corresponding to the maximum probability is reported as the recognized letter [34], [35]. Compared with other techniques, Neural Networks and Hidden Markov Models are more often used for handwriting recognition [36].

Basically, we distinguish between statistical methods (relying on Hidden Markov models or neural networks) and structured and rule-based methods including the following:

Statistical Methods

Hidden Markov Model: HMMs consist of two processes. The underlying process is hidden and contains the state. The observable process contains the output which is visible.

The states have probability distributions over the possible output tokens. The further behavior of the system depends on its present state [34].

HMMs based on word models have the problem that the model set can grow quite large. Because of this, systems using letter models have become very popular.

Neural Networks (NNs): This method for classification has become popular since the 1980s [30]. NNs consist of multiple layers (input, output and hidden). Feed-forward neural networks are mostly used. The ability to train an NN and the back propagation of errors are the main advantages. A comparative study regarding NNs for online handwritten character recognition was conducted by [37].

Fuzzy Logic (FL): Each Fuzzy system is realized in three steps.

1) Fuzzification: Based on the features extracted in the further step the fuzzy sets could be generated easily.

2) Rule Application: The fuzzy sets are evaluated with the rules written for the system.

3) Defuzzification: In the last phase the output is generated [38], [39].

3 State-of-the-Art in Handwriting Recognition Applications

In the following, we briefly discuss the work in relation to the most notable products in handwriting recognition and list the major advantages and drawbacks.

Calligrapher SDK: The application, which we have developed and present in this paper is based on the use of Calligrapher SDK [40].

This recognition technology uses fuzzy logic and neuronal networks. Calligrapher is based on an integrated dictionary, which is used for the modeling process. It recognizes dictionary words from its main user-defined dictionary, as well as non-dictionary words, such as names, numbers and mixed alphanumeric combinations. The Calligrapher SDK provides automatic segmentation of handwritten text into words and automatically differentiates between vocabulary and non-vocabulary words, and between words and arbitrary alphanumeric strings. Further it supports several styles of handwriting, such as cursive, print and a mixed cursive/print style.

Advantages: The application provides many possibilities for the end user.

Disadvantages: The main problem is that it cannot be adapted to a specific end user.

Microsoft Tablet PC: This recognizer works with the Optical Character Recognition and the Convolutional Neural Networks. Such Neural Networks do not need feature vectors as input. The Tablet PC is also able to adapt to a new user during a training phase [41].

Advantages: The system provides many possibilities. There is a higher recognition rate of subsequently entered words because the detection depends on an integrated Dictionary.

Disadvantages: Users are given many unsolicited hints in order to use the device properly. This suggests that the adjustment to the user is not working very well and disrupts smooth functioning.

WritePad: This is a handwriting recognition system developed for iPhone, iPod and iPad Touch devices. The user can write directly onto the display using a finger or an AluPen. WritePad can recognize all styles of writing. It adapts to the user's style of writing, so it takes time until the user can use it with a lower error rate. Furthermore, it has an integrated shorthand feature, which allows the user to enter frequently used text quickly. To use the system properly, Apple offers an exhaustive tutorial. The user has to write largely and clearly for a correct translation. WritePad also includes an auto-corrector; however, this currently supports only English (Phatware, 2008). Meanwhile, Phatware launched an improved version of their advanced handwriting recognition Android app, WritePad in the Android Market (for less than 5 EUR). It supports different handwriting styles such as print, cursive or mixed. It supports the new pen-enabled tablets, such as Samsung Galaxy Note and HTC Jetstream.

Advantages: Through the training phase, the system can adapt to the writing style of the user.

Disadvantages: The user needs patience because the learning process can take longer in some circumstances.

HWPen: HWPen is a handwriting recognition tool which has already been published in 2008 for Apple devices. The software was developed by the company Hanwang.com.cn, mainly for the Chinese language. The system is heavily based on Graffiti. The adjustment period is longer because the user has first to learn the art of writing. However, similar to Graffiti, the system works very efficiently once mastered (Bailey 2008) (HWPen 2008).

Advantages: Since all characters differ greatly, HWPen has a very good detection.

Disadvantages: The user has to learn a new way of writing.

CellWriter: This is an open source HWR-System for Linux. CellWriter is based on the user’s style of writing.

Therefore, a training session must be completed before use. Each character must be written in a separate cell. The system provides a drop-down list of other matches if the recognized result is wrong [42].

Advantages: It provides a word recognition feature.

Disadvantages: CellWriter is only available for Linux.

MyScriptStylus: This HWR-System is based on the latest version of MyScript and can run on Windows, Mac and Linux. The software can recognize about 26 different languages. It provides a lot of different modes, such as Writing Pad mode, in which all kinds of writing (cursive, digit, hand printed) can be recognized. For a better recognition the Character Pad mode can be used, which works similar to CellWriter, whereby the user has to input the letters in cells. Even if the system can work without a training phase, a personal dictionary should be created for better accuracy. This software also provides a list of alternatives in the case of a wrong recognition [43].

Advantages: A lot of language packages and different styles are provided.

Disadvantages: The activation code for the use costs about 40 EUR (without the calculator module).

Except for Graffiti and HWPen, all of the described systems try to give the user as much freedom in writing as possible. However, this leads to an accuracy rating worse than that of strict systems.

On the other hand, the big disadvantage of recognition systems like Graffiti is that the user has to learn a totally new art of writing.

No matter which path one follows, in both cases the user has to work with the device for some time to learn how to write clearly and precisely. This is the reason why HWR-Systems are not widely accepted, as the majority of the users typically do not want to spend much time for the learning phase.

In the following we present some Android Apps:

Writepad Stylus: Writepad Stylus is made specifically for stylus handwriting on a tablet. The software only records the writing done with a stylus, recognition of words written with a finger is not addressed by WritePad Stylus. The app offers convenience features like lasso erase (drawing a closed path to erase everything inside the this path), full zoom (holding the zoom button enables pinch zooming to any magnification), tablet flip and an out-scroll button. The stylus being used is required to have a soft rubber tip.

Advantages: No lag or jitter between the stylus movement and screen response, lots of convenience features, supports thicker tip styluses as well.

Disadvantages: Only records the writing with a stylus, no support for writing with finger.

Graffiti Pro: Graffiti Pro is a keyboard replacement for Android that uses the stroke-based handwriting recognition system text input system made popular by Palm™ PDAs running PalmOS™. With Graffiti, a user no longer types but draws Graffiti characters with your finger or a compatible stylus. Graffiti characters are mostly single-stroke drawings that closely match the usual alphabet, but are simplified to make entry faster and easier. For example, the letter "A" is entered with a stroke that looks like an upside-down "V", saving time that you do not need to cross the "A" in the middle. Same for the letter "T", which is entered almost like a "7". There are text and numeric input areas, improving the recognition of your input. Strokes drawn in the text area will only be interpreted as letters; strokes in the numeric area will be interpreted as numbers.

Advantages: Due to the use of so-called Graffitis, the app supports achieving a good compromise between speed and precision. It supports stylus as well as finger writing. For a comparison between unistrokes and Graffiti see [44], [45].

Disadvantages: Potential users have to learn the Graffiti alphabet, which is supported by a specific help feature.

DioPen™ Handwriting & Keyboard: DioPen™ is an input method editor that supports natural handwriting styles with high accuracy, developed by Diotek. In addition to the handwriting support the app provides a full QWERTY keyboard and supports a variety of languages (including English, Spanish, Italian, Korean, German, Durch, French). DioPen™ can be used with pen and fingers (even on a small display).

Advantages: Supports writing with finger on a small display as well as a number of languages.

Disadvantages: Many users report that the app is difficult to use when writing with a finger on a small device, moreover, many users reported that the app crashes.

MobileWrite: MobileWrite intends to fully allow for entering text by handwriting on the screen instead of typing on the keyboard. Text is entered by handwriting either printed or Graffiti letters, instead of typing on the keyboard. It's an alternative to onscreen keyboard and the real keyboard. Using a stylus improves the speed and accuracy. Notably all keyboard letters and keyboard symbols are supported.

Advantages: Supports handwriting and Graffiti letters and is a alternative to an onscreen or real keyboard. All keyboard letters are supported.

Disadvantages: Potential users have to learn the Graffiti alphabet.

SCUT gPen: SCUT gPen is a handwriting input method released by SCUT-HCII Laboratory of South China University of Technology (http://www.hcii-lab.net/gpen). gPen supports Chinese character sets, English letters, numbers and punctuations and more than 100 types of handwriting symbols. gPen also implements phrase association and an English keyboard.

Advantages: Supports the complex Chinese character set.

Disadvantages: Some of the users have complained about the overall usability.

4 Conclusions and Future Outlook

Generally the interest in using handwriting recognition will rather drop in the future (c.f. with Steve Jobs "who needs a stylus") – although Apple has made a new patent application in handwriting and input recognition via pen [1]

The reason for not using a stylus is twofold:

1) the finger is an accepted natural input medium [46], and
2) touch-based computers have gained a tremendous market success.

In future, communication and interaction on the basis of Natural Language Processing (NLP) will become more important.

However, within the professional area of medicine and health care, stylus-based interaction is still a topic of interest, because medical professionals prefer, and are accustomed to the use of a pen, therefore a stylus [6] is a more familiar writing tool.

Consequently, research in that area is still promising.

Although much research in the field of handwriting recognition has been done, recognition algorithms still do not achieve 100% of the high expectations of the users. Handwriting is very individual to every person and identifying characters is still very hard – as described a long time ago by [47].

Nowadays, many people, especially younger people, are connected to social networks, including Facebook, especially by using their smart phones – where today the user interface consists of a touch screen. Data acquisition is mostly realized with improved, intelligent virtual keyboards; e.g. with the implementation of a regional error correction [48]. Often they are connected with tactile feedback for touch screen widgets [49], which can improve performance and usability of virtual keyboards on small screens. Handwriting is taught from elementary school on and nearly everyone learns handwriting at school. Therefore, handwriting recognition is a very important technology for the input interfaces of mobile computers. However, today, even children get used to the QWERTY layout keyboard from elementary school. Consequently, interface designers can assume that nearly everyone is experienced in using a QWERTY layout keyboard.

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