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Original Citation

Meng, Zhaozong, Lu, Joan and Sawsaa, Ahlam (2013) Integrating Smartphone’s Intelligent Techniques on Authentication in Mobile Exam Login Process. In: Computational Collective Intelligence. Technologies and Applications: 5th International Conference, ICCCI 2013, Craiova, Romania, September 11-13, 2013, Proceedings. Lecture Notes in Computer Science (8083). Springer, London, pp. 130-142. ISBN 978-3-642-40494-8

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Integrating Smartphone's Intelligent Techniques on Authentication in Mobile Exam Login Process

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Abstract. The emerging build-in sensing techniques create opportunities for Human-Computer Interaction capability of the mobile devices. This investigation explores novel build-in sensing techniques and relevant computation intensive algorithms to enhance the operational efficiency and usability of mobile applications. A case study on mobile application authentication involving touch screen manual input, camera barcode scanning, NFC recognition is implemented. Qualitative and quantitative evaluations on usability, efficiency, stability, and accuracy of user operation are examined on mainstream mobile platforms. Result illustrates the advantage of the proposed scheme and verifies the feasibility to enhance user-mobile interaction with mobile sensing techniques.

Keywords: Mobile Computing, Mobile Application, Human-Computer Interaction (HCI), Barcode scanning, Near Field Communication (NFC)

1 Introduction

The Smartphone today can be used for some computing tasks intelligently assisting people's activities with build-in sensors in many different scenarios in data tailoring, navigation, recommendation, etc. [1]. However, the mobile devices are limited in user interaction, that is information representation and data input [2]. Usability, simplicity, and efficiency become crucial concerns of user experience of mobile applications.

However, mobile devices create new ways to enhance the human phone interaction of mobile applications with the novel sensing techniques [3]. Smartphone oriented applications can be reached by: (1) Employing novel build-in hardware and sensing techniques to replace the traditional complex operations, and (2) Utilizing the computation intensive algorithms to reduce the time consuming and error prone tasks. The intelligent sensing technique is critical support for the Smartphones to be able to attract over one billion users worldwide [4].

There are investigations attempting to use the speech and visual information on mobile devices for user interaction, and some motion sensors and recognition modules such as accelerometer and NFC are also drawing attentions [5]. Feng et al. reviewed mobile search and presented speech-based method and multimodal interaction to optimize the efficiency of mobile search [6]. Hannuksela et al. designed an interaction for camera enabled devices to write just by moving the device, using discrete cosine transform and k-Nearest Neighbour rule to discriminate feature and classification, and created a recognition rates ranged from 92% to 98% [7]. Broll et al. presented a Java ME prototype of Physical Mobile Interaction (PMI) paradigm supporting and facilitating mobile interaction with services through the interaction with physical objects, such as through NFC, pointing through visual marker recognition, and direct input through standard input widgets [8]. These techniques convert human interaction to a form that can be easily captured by mobile devices. Thus, it improves the interaction and makes it easy to operate for some use cases. However, we can hardly find studies evaluating the promising novel user interaction techniques, especially for the heterogeneous mobile platforms which are limited in user interaction.

This investigation aims to verify the feasibility of utilizing the build-in sensing techniques to create innovative user interaction approaches for the mobile applications, and determine the affecting factors and underlying limitations of these techniques on different mobile platforms. This work employs the mobile application user authentication as a use case and implements innovative sensing techniques to enhance the usability and efficiency of operation compared with traditional touch screen input.

2 A Case Study - User Authentication with Smartphone Sensing Technologies

2.1 Background

Unlike traditional examination entries, this project implements Smartphone sensing technology into mobile examination system (MES) to authenticate users entering the examination system. As each student has a unique ID card with a barcode on the card and a NFC chip, the camera and NFC technique can be used for user identification and authentication to simplify the operation and improve the speed and accuracy. The accelerometer can be used for user interaction with specific actions such as shaking (see Fig. 1).

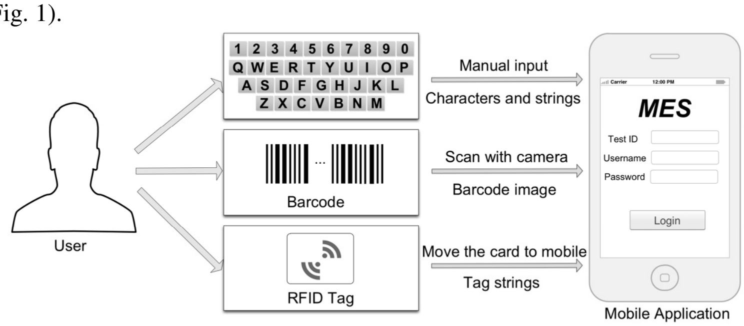


Fig. 1. Technique methods employed in the case study

In order to verify the methods to improve the efficiency and usability of mobile based applications, three user interaction techniques such as touch screen input, student ID card barcode scanning, and student ID barcode NFC recognition are designed and implemented on the latest mobile platforms as shown in Fig.1.

The attributes that can be used to assess the efficiency and usability of the sensing technologies include easy to use, operation speed, error rate, vulnerable to inference, computation intensity, arbitrary degree, and use cases [9]. The evaluation of the user interaction in the case study is focused on the comparison of performance of these approaches and the determination of how the performance of these techniques varies on the heterogeneous mobile platforms.

2.2 System Design

2.2.1 System Architecture of MES User Authentication Module

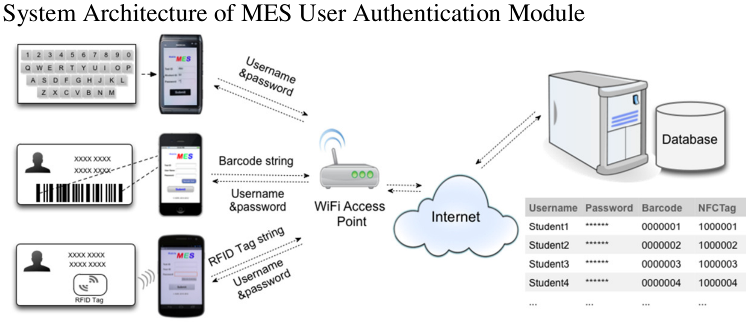


Fig. 2. System architecture of user authentication

The MES is a cross-platform system for the mainstream mobile operating systems, such as Apple iOS, Google Android, Windows Phone 7, and Symbian^3. The system architecture is described in Fig. 2. The accounts of the authorized users are stored in the database of the backend server. When the user login with barcode or NFC magnetic card, the mobile device first obtains data from the barcode or NFC and then accesses the bounded username and password from remote server for login.

2.2.2 Barcode Scanning – A Camera based Computation Intensive Approach

1. Student ID card Barcode Format
The formats for barcodes vary in different areas, the student ID barcode for most universities in the UK is a proprietary format widely used in libraries, which is named Telepen. The Telepen symbology was devised by George Sim, Chairman of SB Electronic System Limited in early 1972. The specification of this symbology is presented in [10]. Compactness and security are advantages of the Telepen symbology.

2. Encoding Format of Telepen Barcode
The information of the barcode formats is encoded and represented by the wide and narrow bars and spaces. The barcode of Telepen format consists of only four patterns

of bar and space pairs (see Fig. 3). Let the barcode shown in Fig. 4 be a sample barcode, the encoding method is introduced as follows.

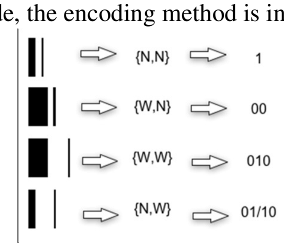


Fig. 3. Patterns of Telepen format

Fig. 4. A sample Telepen barcode

In each Telepen barcode there is a specific beginning and an ending segment. As shown in Fig. 4, the first and the last segments are the start and end of the whole barcode respectively. Besides, seg1 - seg5 are data segments, and segment 6 is the check segment. Each segment is encoded with the patterns pairs in Fig. 3.

Take Seg1 in Fig. 4 for example, the corresponding patterns in the segment are:

Patterns [Seg1] = {{W,N}, {N,N}, {W,N}, {N,N}, {W,N}}

Then, comparing with the encoding digit pairs of each pattern in Fig. 3, the binary digit of the segment Binary[Seg1] can be obtained: 00100100. The binary digit is 8-bit even-parity, the initial value can be obtained with equation (1):

$$\text{value\_init} = \text{decoded\_byte} \ \& \ 0x7F \tag{1}$$

Then, the decimal data of segment 1 Dec[Seg1] is reversed digit of the initial value of Binary [Seg1]: $1\times2^5 + 1\times2^2 = 36$. Using the same method, the decimal data of the data segment Dec[barcode] can be obtained: {95,36,100,54,87,37,67,122}. For verification, the data should meet equation (2):

$$(127 - \sum \text{Dec}[\text{Seg } i]) \ \%127 = \text{Dec}[\text{Check}] \tag{2}$$

For sample barcode, the verification value is: 127 - (36+100+54+87+37)%127 = 67, which equals to the value of the check segment. Then, the data segments subtract 27, the data of the barcode Dec_barcode[dataSeg] can be obtained: {09,73,27,60,10}.

Then, the string ‘0973276010’ is the encoded data of the sample barcode in Fig. 4.

3. Barcode Scanning based on Image Processing.

Most of the barcode readers are laser scanners which work with PC applications. On mobile devices, the barcode can be gathered with the build-in camera, and the decoding can be done with image processing algorithm with the workflow in Fig. 5.

The decoding algorithm extracts the encoded data from the camera gathered images. It comprises the format recognition, pattern matching, 8-bit parity checking, result verification, and length checking. In addition, the system needs some preparations such as camera initialization, camera lens focusing, image acquisition, etc. shown in Fig. 5. The data normalization and pattern matching algorithm are the major concerns. The barcode scanning module is embedded into mobile client applications of MES project on the four mobile platforms with some resource from [11].

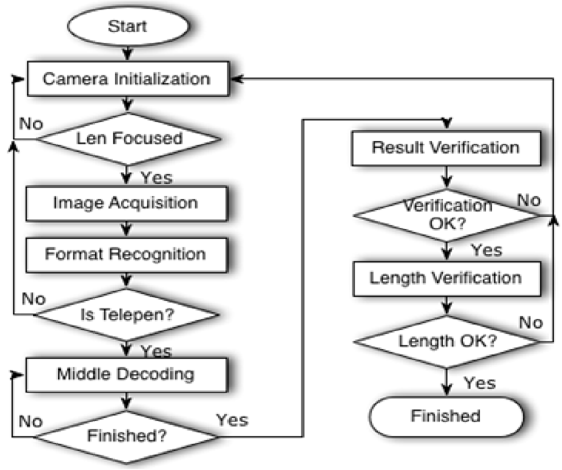


Fig. 5. Flow chart of barcode scanning module

2.2.3 NFC Recognition – A Radio Frequency Identification Technique
The NFC technique is a subset of RFID and limits the range of communication within 4 inches which is strong in security for some use cases. The strength of NFC technology is its ability to precisely identify objects and at low cost [12]. Thus, it becomes a fast growing area of research and application in the recent years.

The application of NFC recognition on mobile devices is a new technology for the Smartphone and Tablets. In this investigation, a NFC enabled mobile phone Samsung Google Nexus is selected as a test platform. The main purpose is to compare the different methods on the same device. When the NFC module is enabled, students just move their student ID cards close the mobile device to login the system immediately.

3 Experiments and Evaluation

Barcode scanning and NFC recognition is implemented for the authentication in MES application. The barcode scanning is implemented on four mobile platforms iOS, Android, Windows Phone 7, and Symbian^3. The NFC magnetic card login is implemented on Android Phone Galaxy Nexus. Experiments are carried out to test and compare the operation, speed and error rate of the three interaction approaches. Performance evaluation of the different methods on different platforms is conducted.

3.1 Simplified Operations using the Interaction Techniques

3.1.1 Barcode Scanning Approach
The login operation can be done with such steps: firstly, launch the MES application on mobile devices and input the Test ID. Then, follow the steps1, 2, and 3 in Fig. 6. (1) Shake the phone or press “Barcode scan” button, then the camera is opened and

scanning is initiated; (2) Target the red line in the camera vision over the barcode till the scanning finishes; (3) Confirm matched ID to login.

Fig. 6. Work flow of the barcode scanning module on iOS platform

With barcode scanning, the user just needs to shake the phone and target the barcode in the camera vision. It is much easier compared with operations on soft keypad.

3.1.2 NFC Recognition Approach

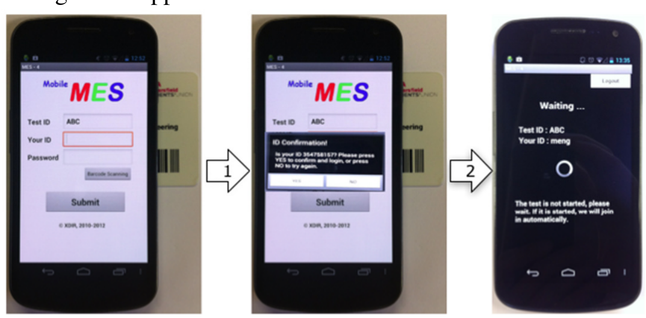


Fig. 7. Work flow of NFC recognition approach

The NFC recognition is implemented on an Android device Nexus S, which also largely simplifies the operations of login process. The operation steps of the login process with a student ID card are: Launch the MES application on mobile devices and input the Test ID. Then, follow steps 1 and 2 in Fig. 7: (1) Move the student ID card close to the phone, till the recognition is finished; (2) Confirm the ID to login.

The NFC recognition approach converts the operation on the soft keyboard to moving the student ID card close to the mobile, which is much easier and convenient.

3.2 Testing of the Interaction Techniques

The testing aims to provide the answers to the following questions:

- How the technologies enhance the usability and efficiency of mobile applications?
- What are the strengths and weakness of these technologies in mobile applications?

- What are the influencing factors of these technologies?
- How they differ among the different mobile hardware and software platforms?

With these questions, the approaches implemented in the system including the touch screen manual input, barcode scanning, and NFC recognition are tested separately. The parameters to be measured are: speed (time spent) and error rate. The mean value and standard deviation (STDEV) of time spent can be calculated accordingly for further analysis. Mean value can be used to estimate the real value of some parameters, and standard deviation is a parameter that can be used to evaluate dispersion degree. Thus, they are used to evaluate efficiency and stability of the approaches.

The strategies for the testing and evaluation are descried as below:

- Test the techniques on the same platform to evaluate the interaction techniques
- Test the same technique on the different platforms to examine its performance
- Discuss the underlying influencing factors based on the testing results

As some methods such as the barcode scanning is easy to be affected by the ambient environment such as brightness of illumination and light reflection, the testing of different devices are expected to be done under the identical condition. The account to be used is randomly generated by specially designed algorithm, and each of the method on different device is repeatedly tested for 20 times.

1. Devices used in the testing

Platforms	Devices	OS Version	Camera (Pixels)	Screen(Inches)
iOS	Apple iPhone 4s	iOS 4.3.5	5M	3.5
Android	Samsung Galaxy Nexus	Android 4.1.1	5M	4.65
WP7	HTC HD2	WP 7.1	5M	4.3
Symbian	Nokia N8	Symbian^3	12M	3.5

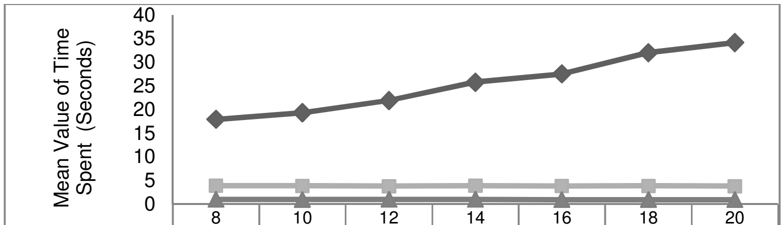
The devices to be used in the test are required to cover the mainstream mobile operating systems. The devices used in the testing are listed in Table 1.

The speed of the three user interaction techniques is tested. The lengths of username and password are set from 8 to 20 in even values. The touch screen, barcode scanning, and NFC recognition are tested separately with the same user. The time is gathered using the timer function on the mobile platform, and the accuracy is 1 millisecond. Timer starts and ends in the tests are:

- Touch screen: From launching the application to pressing the submit button
- Barcode scanning: From initiation of scanning till account is shown and confirmation is required
- NFC recognition: From launching the application till account is shown and confirmation is required.

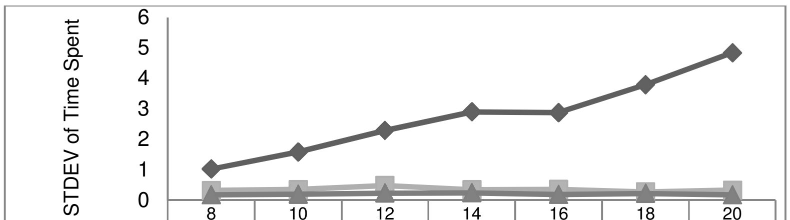
3.2.1 Performance Analysis of the Three Interaction Techniques

The testing results of the mean values and standard deviations of the time spent on Android device Galaxy Nexus are given in Fig. 8 and Fig. 9.



	8	10	12	14	16	18	20
Touch	17.946	19.341	21.948	25.826	27.557	32.048	34.167
Barcode	3.888	3.868	3.808	3.883	3.839	3.851	3.806
NFC	1.039	1.017	1.036	1.034	0.963	0.974	0.974

Fig. 8. Mean value of time spent (Seconds) of three techniques on Galaxy Nexus



	8	10	12	14	16	18	20
Touch	1.021	1.578	2.284	2.899	2.874	3.791	4.837
Barcode	0.317	0.346	0.478	0.342	0.353	0.273	0.328
NFC	0.174	0.192	0.232	0.244	0.183	0.223	0.175

Fig. 9. Standard deviation of time spent of three techniques on Galaxy Nexus

From Fig. 8, it is found that NFC approach is the fastest (Average[MEAN, STDEV]=[1.005, 0.203]), barcode scanning is medium (Average[MEAN, STDEV]= [3.849, 0.348]), and the touch screen manual input is the slowest (Average[MEAN, STDEV]=[25.548, 2.755]). Thus, the barcode and NFC technique is more efficient than touch screen for the interaction. From the curves in Fig. 9, it is clear that the time spent in the interaction regularly increases with the length of information input using the touch screen manual input approach. While it is consistent for the barcode scanning and NFC recognition, no matter how long the information to input is.

From Fig. 9, it is found that the standard deviation of the gathered data varies. The standard deviation of touch screen manual input increases with the length of the input data. That means the longer the input data is, the more uncertainty of the time spent of the input will be. While the standard deviation of the other two approaches remains small and varies smoothly. Namely, no matter how long the data to input, the time spent is constant. The barcode scanning and NFC is more stable in the interaction.

3.2.2 Performance Analysis of Interaction Techniques on Different Platforms

The touch screen manual input and barcode scanning on different mobile platforms are also tested with user name and password length of 8 digits that are randomly generated, and the results are given in Fig. 10 and 11. The condition of the testing environment is considered to guarantee that the external affect can be ignored and will not become a critical problem influencing the performance of the system.

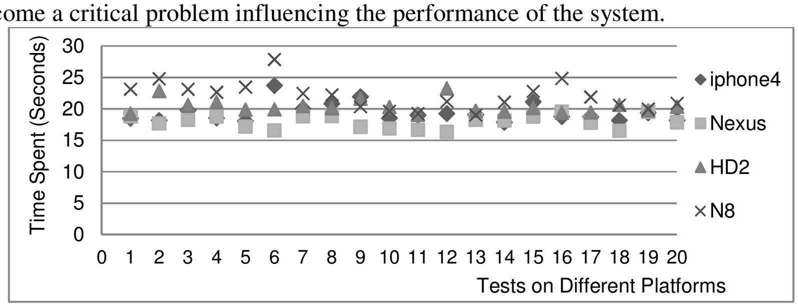


Fig. 10. Time spent (Seconds) by touch screen manual input

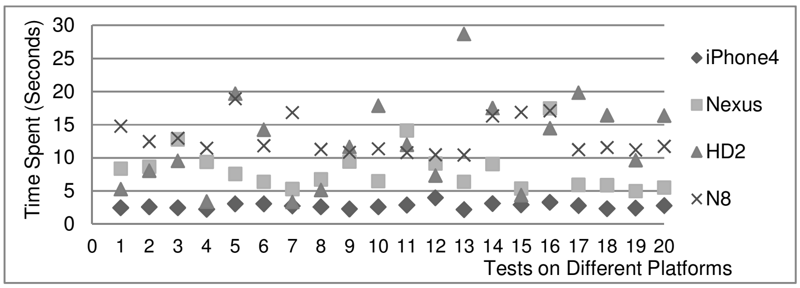
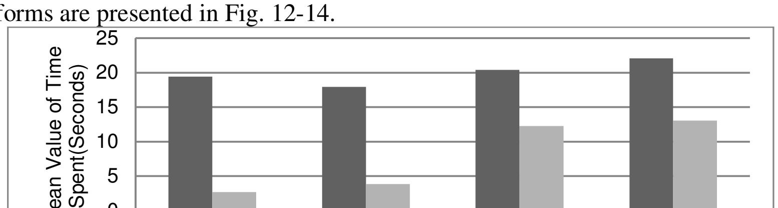


Fig. 11. Time spent (Seconds) by barcode scanning

With the raw data, the mean value of parameters and standard deviations are calculated to evaluate the efficiency and stability. The mean value, standard deviation, and error rate of the two technologies barcode scanning and NFC recognition on different platforms are presented in Fig. 12-14.



	iPhone4	Nexus	HD2	N8
Touch	19.4	17.946	20.394	22.085
Barcode	2.687	3.888	12.247	13.025

Fig. 12. Time spent (seconds) of touch screen and barcode scanning

Fig. 12 shows the mean time spent in the user authentication in touch screen manual input and barcode scanning. It reveals that the barcode scanning approach is faster than the touch screen, especially on iPhone4 (MEAN=2.687S) and Galaxy Nexus (MEAN=3.888S). Moreover, the operation speed of an approach varies on the different mobile platforms. For manual input method, the operation on Galaxy Nexus (MEAN=17.946S) is the fastest because of the biggest screen size (4.65 Inches). Conversely, the operation on Nokia N8 (MEAN=22.085S) is the slowest due to the smallest screen size (3.5 Inches) and the interface is not convenient as that of iPhone4 (MEAN=19.400S) with the same size. For barcode scanning, the operation speeds vary remarkably across mobile platforms. The reason may lie in the control efficiency of the camera and the quality of camera lens. The HTC HD2 (MEAN=12.247S) and Nokia N8 (MEAN=13.025S) are much slower, because the control of the camera is not efficient and it adjusts again and again in the scanning.

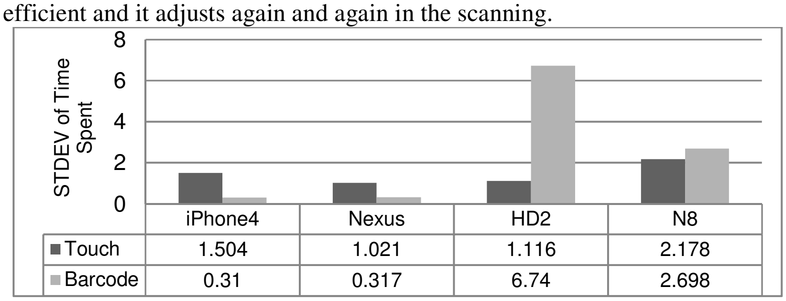


Fig. 13. Standard deviation and of touch screen and barcode scanning

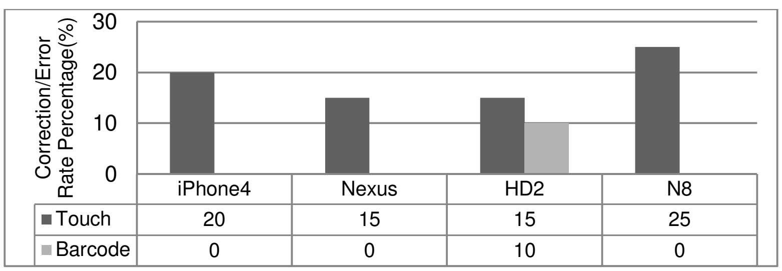


Fig. 14. Correction rate (touch screen) and error rate (barcode scanning)

Fig. 13 shows the standard deviation of time spent in user authentication of these two technologies. The results illustrate that the standard deviation of the manual input on different devices is basically consistent. That is because manual input is not easily affected by some objective conditions. Conversely, the barcode approach is high in standard deviation except the iPhone4 (STDEV=0.310) and Galaxy Nexus (STDEV=0.317) as the camera on iPhone 4 and Galaxy Nexus is of high quality and focuses fast. The Nokia N8 (STDEV=2.698) is high in standard deviation because the control of the camera is not very fluent, and the HTC HD2 (STDEV=6.74) is high in speed standard deviation because the control of the camera is very slow. Besides the focus speed of the camera, the quality of image is also an influencing factor.

Finally, Fig. 14 depicts the correction rate in touch screen manual input and error rate in barcode scanning operations. The correction rate is calculated as the percentage of the corrected logins, which is determined by the screen size and the usability of the soft keypad. The Galaxy Nexus and HTC HD2 are lower in correction because the screen sizes are bigger, and Nokia N8 is the highest because its keys on soft keypad are too small. On the other hand, the error rate of HTC HD2 is high possibly because the camera is susceptible to light intensity and the image quality is usually not good.

3.3 Summary

Table 2. Mobile sensing technologies and the attributes

Attributes	Touch Screen	Camera(Barcode)	NFC
Operation speed	Slow	Fast	Fast
Operation complexity	High	Low	Low
Error rate	High	Low	Low
Vulnerable to interference	True	True	False
Computation intensity	Low	High	Low
Input data arbitrary	High	Low	Low
Use cases (environment)	Arbitrary	Limited	Arbitrary
Generality &Compatibility	Arbitrary	Native App	Native App

Table 2 summarizes the three methods and their performance in user interaction. All the listed attributes may affect the efficiency and usability of the interaction technologies applied in mobile applications. The touch screen is slow and complex in operation, high in error rate of operation, vulnerable to interference such as user behavior, its strength is low in computation intensity, input arbitrary information, and can be used in any environment and any kind of applications. The camera barcode scanning is fast in operation speed and low in operation complexity and error rate, but it is vulnerable to interference, high in computation intensity, input only fixed information, and can be used only in appropriate environment and with mobile native applications. The NFC recognition approach is similar to camera barcode scanning, but it is resistant to interference and low in computation intensity.

4 Conclusion

This investigation employs the novel hardware and sensing technologies to simplify the user interaction and promote the efficiency and usability of mobile applications. The barcode scanning and NFC recognition methods are successfully implemented on the mainstream mobile operating systems. Result verifies the feasibility and advantages they are used to improve the user interaction of mobile applications.

From the evaluation, it is evident that the application of the technologies can effectively help relieve the inherent problems in operational efficiency of touch screen manual input because of the limited screen size. These technologies convert the manual keyboard input operation into simple and convenient actions. It firstly simplifies the operations and accelerates the speed of input, and then reduces error rate in the operations. The efficiency and usability of the interaction is therefore raised.

The performance of interaction techniques differs in speed and accuracy among the mobile platforms, depending on the capability of the hardware module and software platform. Due to the heterogeneity in mobile devices, how much the sensing technology can enhance user interaction dependents on the coordination of hardware and related processing algorithms. In addition, from the testing we also find that sensing technologies may be affected by ambient environments. Therefore, the technologies can make sense only when the interference in the ambient environment is acceptable.

Acknowledgements

This research project has been funded with support from the European Commission, Project Number: 511485-LLP-1-2010-1-NO-KA3-KA3MP. The views expressed in this publication are those of the authors and do not necessarily represent the views of the Commission. The Commission cannot be held responsible for any use which may be made of the information contained therein.

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