AUTO-ID LABS

Evaluation of 1D Barcode Scanning on Mobile Phones

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Auto-ID Labs White Paper WP-SWNET-029

January 2011

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Software & Network

Originally presented at the Internet of Things 2010 Conference (IOT2010), 29 November – 1 December 2010, Tokyo, Japan.

Abstract

1D or linear barcodes are the black-and-white-striped codes that can be found on most consumer products. This work evaluates existing 1D barcode scanners for mobile phones on their applicability towards consumers. The tested scanners identify the data stored in these codes, and thus enable users of mobile phones to conveniently access related information from the Internet on the go, without having to type in the name of a product. The work compares 11 state-of-the-art scanners in a user study with 20 consumers in a realistic shopping environment. It measures the time per scan, the reliability of the scanners, and performs a qualitative evaluation of the users' comments. The results indicate that, although most of the evaluated scanners are available already, still very few function reliably enough to be useful for consumers. General guidelines for the improvement of mobile 1D barcode scanners are derived.

1. Introduction

With the rise of the iPhone and the Android platform released by Google, the share of smart phones has been constantly growing [1]. A key advantage of smart phones is the ability to access the Internet while on the go [2]. Interaction-wise however, smart phones still fight a number of teething problems, including the cumbersome entry of data.

This can be an obstacle, especially when looking up information about products, since entering product names on mobile phones is not considered an option for consumers [3]. Almost everybody has compared prices or browsed product reviews on the Web. Studies suggest that consumers value access to additional information or services about products on their mobile phone while shopping in a retail store [4], [5].

A recent approach to facilitate the interaction between mobile phones and products is the scanning of glued-on tags. Examples are the scanning of square-shaped two-dimensional barcodes and the scanning of RFID tags. Yet, almost all consumer products are equipped with the black-and-white striped 1D or linear barcodes[1], which makes scanning of these tags using mobile phones the most applicable modality [3]. Scanning 1D barcodes using mobile phones works in a way that a piece of software installed on a mobile phone accesses the phone's camera and, based on an image taken, calculates the code and outputs the number recognized.

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1 Common encoding schemes include EAN13 and UPC12.

Although many of these 1D mobile barcode scanners are on the market already applications using these scanners are only coming up[2]. This may have diverse reasons, including the difficulty of relating product information to a scanned barcode number, rather slow and expensive Internet connections, or a lack of appropriate application concepts and business models. It also remains unknown, how reliable and convenient the available 1D barcode scanners are.

This work contributes an evaluation of 11 software-based 1D barcode scanners for mobile phones (see Table 1) in a comparative study with 20 consumers at the Future Retail Center of SAP Research Switzerland, a realistic shopping location. Our study measures the dependent variables task completion time and, partly implied by the former, the reliability of the tested scanners. In addition, it qualitatively gathers and evaluates consumer comments, such as on the preferred visual user interface and the feedback mechanism upon scanning a barcode.

This work provides value for research and practice. On the one hand it supports researchers and interaction designers of mobile object identification techniques in building an appropriate user experience. On the other hand, it provides mobile application developers with an overview of the usability of currently available solutions. Section 2 gives an overview of relevant related work. Section 3 outlines the selected study design, section 4 presents and interprets the results and section 5 discusses possible usability improvements for mobile barcode scanners.

2. Related work

Besides the works on other mobile identification techniques there has been research investigating 1D barcode detection on mobile phones (e.g. [6]). Numerous works have suggested that mobile phones may be the ideal candidates for enriching real-world interactions with information from the Internet. We build up upon Ballagas et al. [2], who have explored and classified various mobile input modalities. Broll et al. [7] and Rukzio et al. [8] analyze and compare input techniques for interacting with the physical world.

According to these studies, touching and pointing are the preferred interaction techniques if the object in question is within the reach of the user. Von Reischach et al. [3] specifically compare mobile interaction techniques for the identification of consumer products. They suggest mobile barcode scanners to be the most applicable technique for interacting with consumer products, given the diffusion of barcodes today. Our work is the next logical step in the sequence of studies. It distinguishes through an evaluation of specific barcode scanner implementations. Also, it is the first evaluation of mobile interaction with products that is carried out in a realistic retail shopping setting.

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2 e.g. ShopSavvy or Barcoo.

3. Study Design

The study consisted of an introduction, three scans performed for each of the eleven scanners, and an adjacent interview. We utilized a within-subject design. The dependent variables were task completion time and reliability, by which we mean the share of successful scans within a task completion time below 15 seconds. The independent variables were the barcode scanners as listed in Table 1. For each participant the study was recorded on video. We also transcribed comments the participant made during the tasks.

Application	Phone	Operating System
Barcoo	Nokia N78	Symbian OS v9.3 S60 3rd Ed. FP2
BaToo	Nokia N95 8GB	Symbian OS v9.3 S60 3rd Ed. FP1
BeeTagg	Nokia N95 8GB	Symbian OS v9.3 S60 3rd Ed. FP1
CodeICare	iPhone 3GS	iPhone OS 3.0
ixMat	Sony Ericsson K810i	Sony Ericsson Java Platform 7
NeoReader	Nokia N78	Symbian OS v9.3 S60 3rd Ed. FP2
QuickMark	Nokia N95 8GB	Symbian OS v9.3 S60 3rd Ed. FP1
Red Laser	iPhone 3GS	iPhone OS 3.0
SnapABar	HTC Magic	Android 1.5
Zebra Scan	Nokia N95 8GB	Symbian OS v9.3 S60 3rd Ed. FP1
ZXing	HTC Magic	Android 1.5

Table 1: Evaluated barcode scanners

3.1. Influence factors and setup

Whether a barcode can be scanned successfully using a mobile barcode scanner depends on the following factors: the physical properties (weight, shape) of the product, the attributes (size, type, contrast, reflection) of the barcode to be scanned, external factors (since scanning is an optical procedure, the light conditions play a major role), the hardware and software used (especially the camera has a major influence on the results), and the scanning person. We have catered for these factors and selected the following setup for the study:

3.1.1. Products and Tags

For the experiment we deliberately selected three products (see Figure 1) with differing physical properties from from more than 3000 products available in the retail lab: one product was rather heavy in weight and bulky (detergent powder), one rather small product (pesto), and one rather difficult to scan (potato chips) with some light reflection from the package. All products were equipped with EAN 13 barcode tags as most common in retail stores throughout Europe today. Each subject scanned exactly these three products.

Fig. 1: The three test products: chips, detergent and pesto.

3.1.2. Mobile Handsets

We abstracted from the diversity among handsets and tested the applicability of the actual software, choosing the optimal hardware/software combination for each scanner. To achieve this, we took the following approach: We compiled a, to our knowledge, complete list of mobile barcode scanner companies. We asked each scanner provider to send us their software on the device they consider best for their software. We contacted 13 scanner providers in total, of which 2 refused to send a handset, 11 sent their preferred handset (see Figure 2).

Fig. 2: The eleven phones with barcode reader software installed.

Another influence factor we balanced out is that some scanners call a website and only then display the scanned barcode. In order to factor out these delays the time was stopped as soon as the screen of the mobile phone switched to open the Internet browser.

3.1.3. Environment

The study was run in a close-to-reality retail store environment: we had access to a retail lab at SAP Research Switzerland which has been set-up by a supermarket chain and features real products with the goal to investigate the customer experience while displaying new technologies. The light conditions were similar to a realistic supermarket, and other external influencing factors were similar compared to a supermarket environment.

3.1.4. Participants

We recruited 20 participants (9 female and 11 male) for the study. Their average age was 32.9 years with an age range from 17 to 61 years and mixed professional backgrounds. All participants owned a mobile phone.

3.2. Procedure

3.2.1. Introduction

The experiment leader welcomed the participants and explained possible applications of scanning 1D barcodes by mobile phone, such as price comparison or product information. The process of scanning barcodes with a mobile phone was demonstrated. He mentioned to each participant that the actual scanners were to be tested and not the skills of the participants. The experiment staff and their role in the experiment were introduced (one experiment leader, one taking notes, one filming the experiment). The task was explained to the participant. The participant was shown the three predefined products distributed over the supermarket that were to be scanned. For each product, the location of the barcode on the product was shown to the participant (see Figure 3).

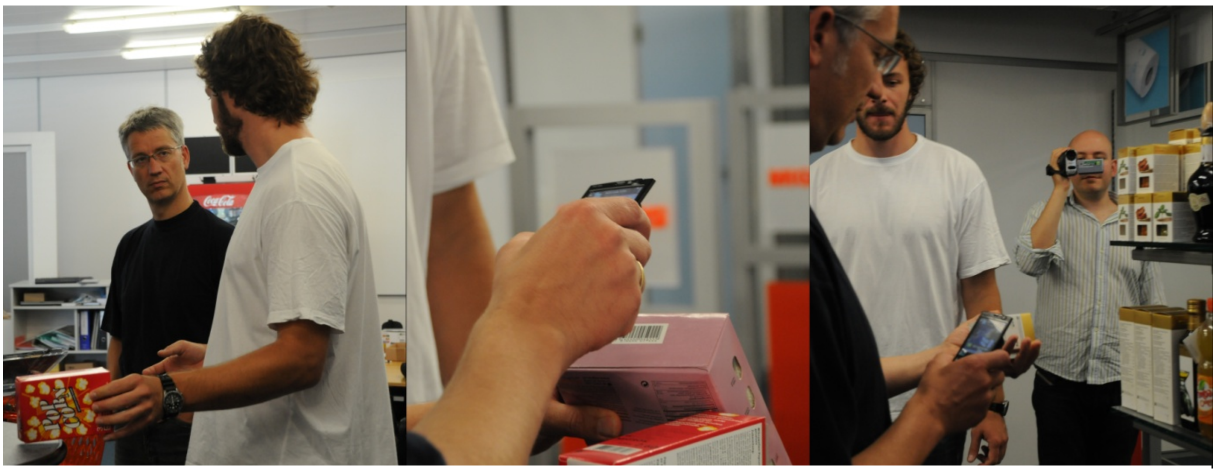

Fig. 3: Procedure: introduction, testing of scanners, scanning of products.

3.2.2. Tasks

The sequence in which the barcode scanners were tested was randomized in such a way that each participant of the study performed three scans with each scanner in a different order (product and scanner sequence randomized). For each scanner the procedure was as follows: the participants received a standardized oral introduction to the barcode scanner on

Fig. 4: Scanning of the three test products chips, detergent, and pesto.

hand: The participants were shown the process of scanning a sample product, orientation of the handset, which buttons to press and how to return to the start screen after successful scanning. The users tested each scanner a couple of times until they confirmed that they felt familiar with them. When the participants expressed readiness, they were asked to take the first of three predefined products from the shelf, locate the barcode and scan it. The time from taking the product off the shelf until the barcode was recognized was measured and the recognized barcode was checked for correctness. If the recognized barcode was wrong it was marked as a false positive. If no barcode was recognized after 15 seconds, the task was stopped and marked as timeout. This task was repeated with the two other predefined products. Remarks from the participant were recorded and noted down.

3.2.3. Interview

Adjacent to the study, we conducted an interview with each of the participants. The participants answered questions about the experiment and if they remembered anything particularly positive or negative. For each subject we asked: how did you feel using the scanners? Do you have any positive or negative remarks? Under what circumstances would you use a mobile barcode scanner when shopping? Each participant was asked which phone she uses normally. The answers were recorded on video and noted in keywords.

4. Results

The main results of the study were about reliability and speed of the tested mobile barcode scanners. We also collected individual feedback on the scanners from the participants' remarks and noted some differences in the way the scanners were implemented.

4.1. Reliability

There were only two scanners which decoded all scanned barcodes correctly used in the study. Two other scanners had an reliability between 90 and 100%, four scanners between 80 and 90%, and three scanners had lower than 60% reliability (see Figure 5).

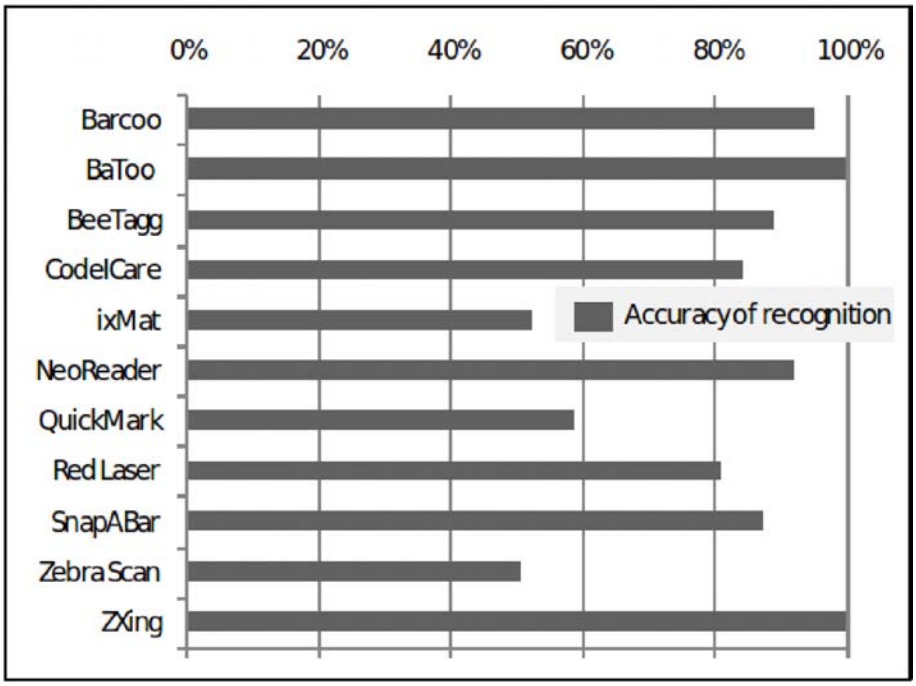

Fig. 5: Reliability of recognition by scanner.

Eight participants experienced audio and vibration feedback to be helpful. Six participants complained about long waiting times. These waiting times were for taking a picture and locally decoding the barcode on the mobile phone. Four participants preferred having a visible scan line instead of a viewfinder window.

4.2. Completion times

The times for a correct scan range were between an average of 3.5 seconds for the fastest scanner and 10.4 seconds for the slowest (see Figure 6). The scanners with the highest reliability, namely BaToo and ZXing, were also the fastest, and the scanners with the lowest reliability were the slowest.

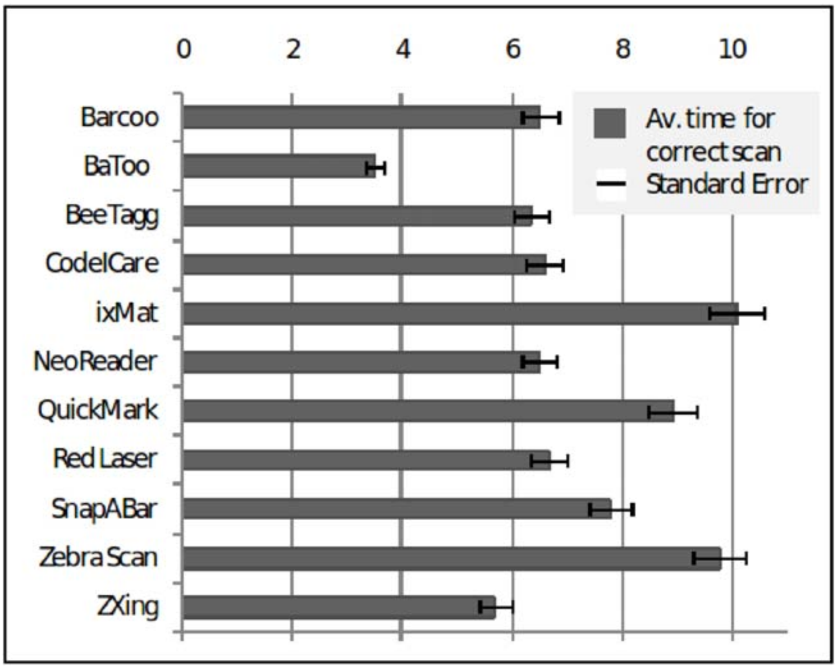

Fig. 6: Average task completion time by scanner.

4.3. Observations

The various scanners we tested differed in terms of the user interfaces and performance of the image to barcode processing. First, there is the design of the visual user interface: Some scanners show a visible scan-line which needs to be aligned horizontally with the barcode, some other scanners display a viewfinder window or a graphical frame where the barcode has to be placed within. Second, there is the way the user receives feedback about the successful recognition of a barcode: Some scanners give audio feedback, some vibrate, some show some visual information, others do nothing. Third, there is the interaction, some scanners require the user to press buttons to either to focus the camera, to trigger recognition, or to proceed for scanning another product. The actual barcode recognition is either performed on the live video frame capture or on a fixed image, a photo taken of the barcode. Taking a picture results in delays and gives the impression of a ”frozen” application, video capture reveals the barcode instantly. Most scanners choose to iterate the focus through several distance steps, whereas some scanners prefer to use a fixed focus which the user has to set once manually. The fixed focus approach is faster once it is set but it is hard to educate users to set the focus. Finally, some scanners require a network connection for successful recognition.

4.4. Interview

From the participants remarks about the scanners during the study we found nine people that reported pressing buttons to make the scanning process cumbersome and less intuitive. Eight participants experienced audio and vibration feedback to be helpful. Six participants complained about long waiting times. These waiting times were for taking a picture and locally decoding the barcode on the mobile phone. Four participants preferred having a visible scan line instead of a viewfinder window.

5. Implications

Although we asked the software providers to send us a handset where their scanner would work best and abstracted from handset diversity, the reliability was still below 90% for seven of the eleven tested scanners (note that this is at almost optimum light conditions). However, from the discussion with study participants we know that people would not use a scanner again if it had been inaccurate several times. In addition, all except one scanner are in average slower than five seconds. However, comments from the users indicate that nobody is willing to spend more than five seconds for a scanning task. Lowering the hurdle for accessing productrelated information is important to make it worthwhile for consumers to try, and even more, to perceive barcode scanning as useful.

5.1. Limitations

There are a couple of limitations that are worthwhile being discussed. Most importantly, we are aware that the hardware, i.e., the devices used for the experiment, influence the performance of the tested barcode scanning software significantly. Although we have taken an approach to mitigate this hardware heterogeneity by asking the software providers to send us the hardware that their scanner works best on, the hardware still influences the results to some extent. In addition, the software-based barcode scanner business is very dynamic, meaning that new versions of the scanners are being released consistently. Consequently, our study describes the performance of the tested scanners at a particular point in time. Given these limitations, we are still convinced that our study is benefitial to the research community, since giving an overview of the performance is only a minor aspect of the study. Instead, the paper gives an overview of the different types of scanners regarding their usablity, and formulates guidelines for the improvement of their usability.

5.2. Guidelines

From the experiment and the discussion with the participants we derive the following requirements for mobile 1D barcode scanners:

Speed: As a rule of thumb, our experiments showed that feedback and performance of a read must not exceed five seconds. Users on the go have only little attention for the application and are rather impatient.

Reliability: Close to 100% reliability is mandatory. Wrong identification of barcodes triggers the display of unrelated information and leads to frustration. The users' tolerance of such flaws is low and users will give up with the application quickly. To achieve sufficient reliability, influence factors like light in the environment, reflection of the barcode, form and shape of barcodes and products, and staining of barcodes need to be considered when designing scanners.

Simple Interaction: An intuitive way of scanning, be it the red scan line for barcodes indicating how to place the phone or the simple notion of touch for NFC, can foster successful adoption. Following the comments that some users made, people prefer a visual scan line over a rectangle and over displaying no orientation hint. Comments also indicate that the viewfinder window should not contain any other information, since this distracts people from scanning a barcode. Also, no buttons should have to be pressed. The read has to be performed right away.

Distinguished Feedback: Users demand quick but dedicated feedback, upon a performed read. The actual modality - vibration, sound, visual feedback - depends on personal preferences and should be configurable.

But also besides the factors tested in our study, a number of practical problems remain unsolved:

Handset Diversity: The platform and handset diversity is a major obstacle for applications to gain momentum. Our pretests showed that some scanners work great on some handsets and on other handsets they do not work at all. Again others work better on one phone of a platform than on the other, due to different image qualities the camera can provide. And then there are scanners that work on one phone of a platform, but do not at all work on another phone of that platform (e.g. Batoo, works on Nokia's N95, but not on Nokia's N96).

Business Models: The creation of sustainable business models for 1D barcode scanners is another challenge as consumers only see a benefit in using barcode-scanning mobile applications if they are not required to pay for it. Additionally, the superior experience of users reading 2D barcodes with their phones (better performance due to increased redundancy in the codes), e.g. from magazines and public displays, puts pressure on 1D barcode scanners to achieve comparable performance.

Today, 1D barcodes dominate auto-identification of items in retail. If major retail players will ever switch to RFID, RFID readers could also be part of mobile phones achieving better performance [3].

6. Conclusions

Our study showed that the low adoption of mobile 1D scanners can be explained by the fact that most of them are not applicable yet, many are still slow and unreliable. Instead, the public expectation rather is that 1D barcode scanning on mobile phones should be already applicable as the performance 2D barcode scanners suggests. In order to make 1D barcode readers successful, developers should design for speed, reliability, avoid the need to press buttons, and process the data from the continuous video-stream of the mobile phone's camera.

References

[1] R. Want (2009): When cell phones become computers, IEEE Pervasive Computing, vol. 8, no. 2, pp. 2–5, April-June 2009.

[2] R. Ballagas, J. Borchers, M. Rohs, and J. Sheridan (2006): The smart phone: a ubiquitous input device, IEEE Pervasive Computing, vol. 5, no. 1, pp. 70–77, January-March 2006.

[3] F. von Reischach, F. Michahelles, D. Guinard, R. Adelmann, E. Fleisch, and A. Schmidt (2009): An evaluation of product identification techniques for mobile phones, in Proceedings of the 12th IFIP TC13 Conference in Human-Computer Interaction (Interact'09), August 2009, pp. 804–816.

[4] GS1 (2008): GS1 Mobile commerce whitepaper, http://www.gs1.org/docs/mobile/GS1 Mobile Com Whitepaper.pdf, February 2008.

[5] GS1 (2009): GS1 MobileCom extended packaging pilot handbook, http://www.gs1.org/docs/mobile/GS1 Extended Packaging Pilot Handbook.pdf, February 2009.

[6] R. Adelmann (2007): Mobile phone based interaction with everyday products on the go, in Proceedings of the The 2007 International Conference on Next Generation Mobile Applications, Services and Technologies (NGMAST'07), September 2007, pp. 63–69.

[7] G. Broll, S. Siorpaes, E. Rukzio, M. Paolucci, J. Hamard, M. Wagner, and A. Schmidt (2007): Comparing techniques for mobile interaction with objects from the real world, in Pervasive 2007 workshop on Pervasive Mobile Interaction Devices (Permid 2007), May 2007. [Online]. Available: http://eprints.comp.lancs.ac.uk/2062/

[8] E. Rukzio, G. Broll, K. Leichtenstern, and A. Schmidt (2007): Mobile interaction with the real world: An evaluation and comparison of physical mobile interaction techniques, in Proceedings of the 2007 European Conference on Ambient Intelligence (AmI 2007), November 2007, pp. 1–18. [Online]. Available: http://dx.doi.org/10.1007/978-3-540-76652-0.