Acceptance and Usability of Physical Mobile Applications

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ABSTRACT
Physical mobile applications use mobile devices for the interaction with everyday objects to facilitate the interaction with associated information and services. In order to be able to assess their acceptance, usability and interaction design in a systematic way, this paper suggests different categories of physical mobile applications according to common use cases and patterns of interaction with physical objects. A user study was conducted with low-fidelity paper-prototypes to evaluate them. The results will be used for the definition of guidelines and best practices for the development of common physical mobile applications.

Keywords
Physical Mobile Interaction, Physical Mobile Applications

1. INTRODUCTION
During the last years, the advancement of Ubicomp applications has increased the possibilities for interaction with objects, locations or people in the everyday world. This development benefits from the dissemination of technologies like Bluetooth, visual markers, RFID, NFC or GPS. They make it possible to tag objects, make them machine-recognizable and associate them with additional information and services. Complementary, mobile devices provide the technical means for discovering, capturing and using this information.

Physical Mobile Interaction (PMI) [10] takes advantage of these developments as it uses mobile devices to interact with physical objects in order to facilitate the discovery of associated information or services and to make the interaction with them more intuitive and convenient. The increasing opportunities for this kind of mobile interaction are used by a growing number of applications for service discovery and invocation, information, ticketing, mobile payment, advertisement, sharing data or games.

The Simple Mobile Services (SMS) project [13] aims at the development and provision of mobile services that are easy to find, easy to use, easy to set up and easy to trust. In order to make mobile services easier to find and easier to use, the project adopts PMI for the concept of SMS points - physical objects or locations that are tagged and associated with information for the easy discovery and invocation of mobile services. Use case scenarios for SMS points cover a broad range of typical *physical mobile applications (PMA)* that use PMI to facilitate the user's interaction with their own functionalities. These scenarios comprise reading URLs from visual markers, mobile payment via NFC, mobile advertisement using Bluetooth or more complex 2-way interactions, e.g. with an airport check-in terminal.

While much research has been conducted about the design, usability and acceptance of enabling technologies and interaction techniques for PMI, there is little similar work about the applications that employ them. The goal of this paper is to provide a general overview of common PMAs on the background of typical use cases for PMI and patterns of interaction with physical objects. It will assess different categories of PMAs, evaluate their acceptance and point out issues regarding their usability and interaction design. The results of this preliminary evaluation will be used for the future definition of design guidelines and best practices for the development of PMAs in general and interactions with SMS points in particular.

2. RELATED WORK
PMI relies on various enabling technologies to implement the tagging of physical objects with additional information as well as its acquisition through mobile devices. Common technologies comprise RFID, NFC [16], GPS, visual markers (e.g. Semacodes [12], QR Codes [4], Visual Codes [6] …), Bluetooth or infrared beacons [5]. Different interaction techniques have been built on top of these technologies in order to make the interaction with them more familiar and intuitive. Examples are *Touching*, *Pointing*, *Scanning* [9], *Browsing* [14] or *Hovering* [15].

Previous research in this area has evaluated enabling technologies and interaction techniques for PMI: O'Neill et al. [7] explored the usage of NFC in a field study and compared it to visual markers in an experimental evaluation in order to investigate potential usability issues. Geven et al. [3] assessed user experiences with NFC on four different levels of usage: reading from passive objects, verification for services, payment and p2p sharing.

In [9], the interaction techniques *Touching*, *Pointing* and *Scanning* were compared for the selection and usage of smart-home appliances in different contexts of location and activity (e.g. sitting, lying or standing). Similarly, [10] evaluated advantages and disadvantages of the interaction techniques Touching, Pointing, Scanning and User-Mediated Object Selection across different physical mobile applications.

3. CLASSIFICATION OF PHYSICAL MOBILE APPLICATIONS
Today, there are many different use cases for mobile applications that use physical interaction. In order to be able to assess and evaluate them in a systematic way, this paper suggests different

categories of PMAs according to common functionalities without being confined to specific technologies, interaction techniques or use cases. This categorization is based on general patterns of interaction between mobile devices and physical objects on top of enabling technologies and interaction techniques. It regards the properties and roles of devices and objects in the interaction process as well as the way information is used by physical mobile applications. Since this information can be seen as context information, the categorization includes the three features of context-aware applications defined by Dey et al. [2]: *presentation of information*, *automatic execution* and *tagging*.

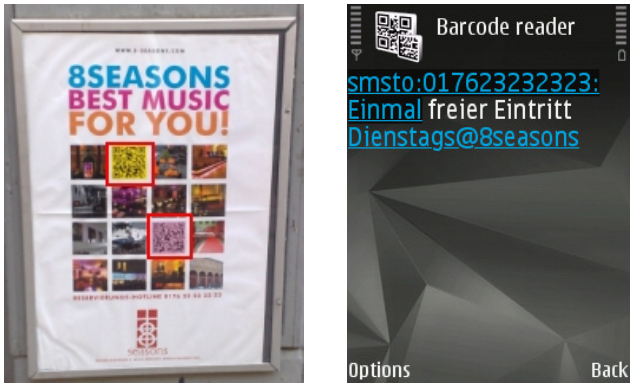
3.1 Presentation of Information

The simplest kind of PMI is using a mobile device to actively read information from tags on physical objects and showing the acquired information to the user. This refers to the homonymous feature of context-aware applications. Depending on available options, the user can decide himself what to do with this information. Typical applications include tagged posters and leaflets, museum guides and information points providing additional information about exhibits or sights.

3.2 Physical Hyperlinks

Similar to the automatic execution of context-aware applications through context information, information acquired from tags can be used to trigger the execution of corresponding actions. Tags act as "*physical hyperlinks*" [6], providing shortcuts to services and reducing complex chains of interaction steps to a simple physical interaction. Thus, physical hyperlinks emphasize the core concept of PMI – simplicity. Instead of opening a message application, typing a number and sending a message to get free admission to a concert, taking a picture of a visual marker (see Figure 1a) can be used to circumvent most of these steps (Figure 1b). Similarly, Salminen et al. [11] have used NFC-tags to shorten Bluetooth-discovery by putting the address of a Bluetooth device on a tag.

Opposite to the mere presentation of information from tags, applications using physical hyperlinks assign information to specific actions, e.g. opening a link in a web browser or calling a phone number, which is automatically triggered upon "clicking" on a physical hyperlink



a) **b)**

Figure 1. Visual marker on a poster (a; red squares) as physical hyperlinks for sending a text message (b)

3.3 Tagging

Opposite to most PMAs, which read information from tags, tagging can be used to write information to the real world and tag its objects with arbitrary information (Figure 2a). Tagging and the presentation of information can be seen as complementary, but they represent different patterns of interaction as one is used to write information to objects, while the other one reads this information. As mobile devices provide more capabilities for reading tags than writing to them, typical applications for tagging are often limited to RFID/NFC-tags or geo-tagging.

a) **b)**

Figure 2. Attaching information to an object with tagging (a) and broadcasting information via a Bluetooth beacon (b)

3.4 Broadcasting

Due to the popularity of RFID tags and visual markers, many use cases for PMAs include passive objects and tags that have their information pulled from them by active mobile devices. Broadcasting employs objects that actively push information to clients, using e.g. Bluetooth or active RFID-tags. In order to receive this information, mobile devices have to activate the necessary technology explicitly. Typical use cases for broadcasting include information points (see Figure 2b) or mobile advertisement. Pushing information to users might offend them as they can easily feel spammed with unwanted information. On the other hand, this information can be filtered according to personal preferences, providing a valuable, context-aware service to users.

3.5 Tag Emulation

Apart from reading information from tags, mobile devices can act as tags themselves, thus emulating them. This category of PMAs is inspired by NFC which explicitly allows devices to be passive and have information read from them by active readers. This interaction pattern covers many popular PMI use cases for smart cards including identification, ticketing, access control or payment. Apart from NFC, PMAs can use visual markers for tag emulation by showing them on their screens.

Similar to physical hyperlinks, this interaction pattern demonstrates the simplicity of PMI: users only have to swipe their devices over a reader to interact with vending machines, doors or barriers in underground stations. Opposite to tagging which requires users to actively write information to passive objects, tag emulation relies on passive devices that provide information to have it acquired by active readers.

3.6 2-Way Interaction

The interaction patterns and PMAs from the previous categories show the simplicity behind PMI. Mobile devices either acquire information from physical objects or provide information themselves in a single interaction step. More complex PMAs carry out more demanding tasks and often comprise several interaction steps with more intelligent objects that actively communicate with mobile devices thus implementing a mutual 2-way interaction between them. An example from the SMS project is the interaction with a check-in terminal at an airport that requires the user to provide information in several steps (see Figure 3). Another example is mobile payment that could comprise several interaction steps to carry out a transaction.

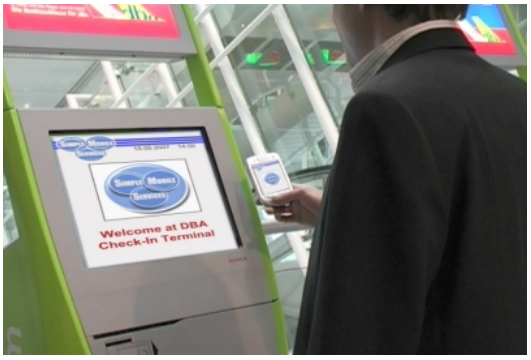


Figure 3. 2-way-interaction with an airport terminal (SMS mock-up)

4. COMPARISON AND EVALUATION

In order to investigate and assess the acceptance, interaction design and usability of different PMAs, a preliminary study was conducted to evaluate the concepts behind the described categories with low-fidelity paper-prototypes.

4.1 Study Setup and Prototype Design

At the beginning of the study, the subjects watched a short video about the SMS project to introduce them to different examples of PMAs. Afterwards, the investigator gave another introduction to different technologies for PMI, especially NFC and visual markers. For the main part of the study, the subjects were asked to use paper-prototypes of different PMAs to carry out 6 tasks representing use cases from each of the suggested categories of PMAs. The tasks were carried out in random order. After each task, the subjects had to fill out a short questionnaire to assess the tested PMA, mainly using 5-point Likert scales.

For each task, the paper-prototypes comprised a mock-up of a PMA on a mobile device and a physical object:

- **Presentation of Information:** Subjects had to read a visual marker on a poster to get information about a concert and save the date for the concert in the phone's calendar.
- **Physical Hyperlinks:** Subjects had to interact with NFC tags on two different posters to get quick access to a weather report and to call a taxi.
- **Tagging:** Subjects had to provide information for a hotel check-in by downloading the registration form from an NFC-tag, filling it out and submitting it to another NFC-tag.
- **Broadcasting:** For this task, the mock-up showed an advertisement pushed from an imaginary Bluetooth beacon.
- **Tag Emulation:** Subjects had to interact with a cash point for mobile payment
- **2-Way Interaction:** Subjects had to interact with a poster to carry out different steps for a quick check-in at an airport.

4.2 Demography

12 subjects participated in the user study (6 male, 6 female). Their age ranges from 22 to 36 with an average of 26,6. 9 participants were students of media informatics, the others had different jobs. All but 2 subjects have owned a mobile phone for an average of 5,8 years. They estimated their experiences with them with an average of 3,2 and their general technical experience with 3,8. Most of the participants don't use mobile services (1,5 average).

4.3 Results

4.3.1 Presentation of Information

11 out of 12 participants would interact with physical objects to get more information about them, which is seen as fast, simple, direct, interesting and does not require searching on the Internet. 8 subjects would use physical interaction to get more information about the advertised concert, while only 1 subject preferred using a mobile web-browser for this task. 3 subjects preferred searching for information about the concert from at home using the Internet.

On average, the interaction between the mobile device and the physical objects was considered to be quite simple (4,1), intuitive (3,9), fast (4,1) and understandable (4,1). 2 subjects did not see the visual tag or preferred an NFC-tag for the interaction.

4.3.2 Physical Hyperlinks

11 out of 12 participants would use physical hyperlinks to invoke services spontaneously as this was considered to be simple, fast and handy. In comparison, 7 subjects would prefer to carry out the tasks by using physical hyperlinks on posters for similar reasons. 6 subjects voted for the traditional usage of mobile phones (call a number, open a URL in a browser) arguing that this is more familiar for them and also independent of physical objects.

On average, the interaction between the mobile device and the physical objects was considered to be very simple (4,9), intuitive (4,3), fast (4,6) and understandable (4,3). In order to improve this application, subjects wanted to call a taxi without making a real call or sending their name and current position to the taxi center.

4.3.3 Tagging

For the hotel check-in scenario, 10 participants would use tagging to provide information about them as this is considered to be simple, saves time and reduces errors. Contrary, 2 subjects denied this time-saving effect or preferred face-to-face contact. Similarly, 7 subjects would use this interaction pattern to provide information, compared to 3 subjects who preferred using a computer and 2 subjects who preferred filling out a paper form.

On average, this interaction pattern was seen as very simple (4,3), intuitive (4,0), fast (4,7) and understandable (4,4). The mock-up of the application faked autocompletion that filled out the hotel registration form after it was downloaded from the NFC-tag. 10 subjects advocated this feature because of its speed - provided they could still edit the suggested data. 2 subjects disliked this feature for security reasons.

4.3.4 Broadcasting

The acceptance of the voucher that was pushed to the subjects from an imaginary Bluetooth beacon as advertisement was divided: 6 subjects would like to receive information or adverts this way because they wouldn't have to look for shops or get up-to date information. 6 subjects disapproved of this kind of interaction, mostly out of fear of getting too much advertising. In general, subjects were definitely afraid to be spammed with too much information or ads (4,3 average), but thought that additional information, e.g. to find a shop, would provide an added value (3,6). 11 subjects would use this kind of application if the received information was adapted to personal interests and preferences, e. g. through filters.

4.3.5 Tag Emulation

For this kind of PMA, the mobile phone emulated a credit card for mobile payment at a cash point using NFC. 9 subjects would use this kind of mobile interaction which was regarded as comfortable and time saving. 3 subjects disapproved of this PMA, because it was seen as unsafe or customer data could be abused. In a direct comparison, 6 subjects would prefer mobile payment and 6 subjects would prefer payment with a credit card. Similarly, subjects were cautious to trust mobile payment (3,0 average), mostly because of security reasons. The interaction between the mobile device and the cash point was more complex than in the previous use cases. Nevertheless, it was seen as very simple (4,7), intuitive (4,4), fast (4,5) and understandable (4,75).

4.3.6 2-Way Interaction

In this scenario, subjects interacted with a poster that guided them through the steps of a check-in service at an airport. 9 out of 12 subjects would use PMI for such a complex task which was regarded as simple and mostly fast (no waiting queue). Subjects who disapproved, preferred human contact at a regular check-in desk or found the interaction with multiple tags laborious. Despite these results, only 4 subjects preferred interacting with the posters over a regular check-in terminal in a direct comparison. The latter was seen as more familiar and provided human contact. Despite the complexity of the interaction with multiple tags on the poster, it was considered to be simple (4,3), intuitive (4,0), fast (4,1) and understandable (4,0). Some subjects did not know how to start the interaction or wanted more guidance.

5. CONCLUSION

This paper suggested a systematic overview of use cases for physical mobile applications by defining common categories based on general patterns of interaction between mobile devices and physical objects. The results of the user study indicate that the defined categories of PMAs – presentation of information, physical hyperlinks, tagging, broadcasting, tag emulation and 2-way interaction – are well understood and accepted.

However, PMI was not that popular when compared to "traditional" means for solving the same tasks, e.g. by calling a phone number or using a web-browser. Given the choice between traditional and physical interaction, roughly half of the subjects voted for the latter across most tested use cases. The study also pointed out or confirmed different issues regarding the usability of PMA, especially with the broadcasting of information and mobile payment through tag emulation. They showed that the acceptance and usability of PMAs can be highly dependent on their value for customers, security issues or the overall complexity of the interaction process.

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