Realising Physical Selection for Mobile Devices

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ABSTRACT
Physical selection offers a promising method for using mobile devices, such as smart phones and personal digital assistants, as tools for communication between a human and the digitally augmented objects and services in the environment. In this paper, we analyse the concept from the technological perspective, and focus on different technologies, which may be used to implement the physical selection paradigm: visual patterns, electromagnetic methods or infrared.

Categories and Subject Descriptors
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Keywords
Physical selection, tangible user interface, mobile phone, natural interaction, RFID, IR, barcodes.

1. INTRODUCTION
Ubiquitous computing inherently includes natural interaction between humans and digital devices embedded in their environment. The desktop metaphor [8] works well in the office, but it is not so well suited to ubiquitous and mobile computing [11]. The limited size of the mobile devices restricts the display area and handheld devices do not support the use of mouse or other common ways of pointing. Also the use of QWERTY keyboards is limited by the size of the mobile devices.

The mobile devices should be able to communicate with the devices and services available locally. Since the location[1] varies, the environment is inherently dynamic. In this respect the situation is very different from an office computer, where the tools (services), e.g. word processing, spreadsheet calculation, and email, are fairly stable. For example using multi-level menus for selection in stable environment is not difficult after the user familiarises her/himself with the tools. In a dynamically changing i.e. mobile environment this is not the case. Therefore, all the means to facilitate usage should be employed. One of these means is tying the available services to their physical counterparts.

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[1] Instead of location, also situation or task can be the variable.

Ideas close to physical selection have been suggested [10,11,4]. Ulmer and Ishii [10] developed the idea of Phicons, which serve as physical icons for the containment, transport and manipulation of online media in an office environment. Their paper does not discuss the role of mobile personal devices, such as smart phones or Personal Digital Assistants (PDAs), but instead rely on fixed devices, such as digital whiteboards, projectors, and printers. Kinderberg and co-workers study infrastructures to support "web presence" for the real world [4], their main idea being connecting physical objects with corresponding web sites. Infrared (IR) beacons, electronic tags or barcodes are suggested for creating the connection. We estimate the application potential to be much larger than accessing web pages associated with physical places or objects.

In this paper the employment of widely used and increasingly popular mobile devices, such as smart phones and PDAs, as a tool for physical selection is suggested. In the physical selection paradigm the interaction between the personal mobile device and a target object or device in the real world is initiated by a physical operation, such as pointing or touching. The function is analogous to selection in the virtual world of a desktop, hence the name.

We briefly describe three examples of using physical selection, derive requirements based on use cases, and then focus on analysing the potential of different technologies which may be used to implement the concept. Finally, the potential of physical browsing as well as future direction of the research is discussed.

2. EXAMPLES OF USE CASES
Three potential use-cases of physical selection are presented. The cases are

Use Case #1: updating the context profile of a mobile phone. The context profile of a mobile phone should relate to the current situation defined largely by the location and the task at hand. The location specific context could be e.g. an office, meeting room, car or home. Changing or updating the context profile of a mobile phone could be done by pointing it at a Context Tag and accepting the new profile, which is downloaded from the tag or from a location specified by the tag. A natural place for Context Tags would be near beside door posts of rooms. In a similar way, task or situation context could be chosen by pointing at physical symbols of each named context with the mobile device.

Use Case #2: Activating a phone call to a person by pointing at her/his picture or a tag in a business card. This would ease the dialling process, which is also error prone especially when the user is moving or preoccupied by some other task. A similar case would be launching any application or function on a mobile device while pointing at a tag, e.g. starting a web-browser and downloading the web-page related to the current object.

Use Case #3: Using a mobile device as a universal remote control for objects, which do not have a complete UI of their own (e.g. home appliances). The control of many everyday devices – thermostats, videos, ovens, washing machines – may in the future be partly delegated to mobile devices. The controlled device could have a tag[2], and by selecting the tag the user would launch a control UI on his/her activating device. This UI can provide significantly more freedom in personalisation and adaptation than any built-in UI can realistically do.

3. REQUIREMENTS FOR PHYSICAL SELECTION

There are many issues related to the implementation of the physical selection paradigm. These include:

1. Physical selection may be based on proximity or pointing. In the case of proximity, the selection is activated by bringing the activating device, e.g. a smart phone, close to the target device. Respectively, in the case of pointing, the activating device is aimed at the target device. In both cases, the maximum distance of activation may vary, but for proximity type of selection, it would be natural to assume "almost touching" as the prevalent case where as in the case of pointing, a maximum distance of up to a few metres seems natural. In the case of pointing, sensitivity to aiming errors and feedback of the aiming direction, e.g., with a visible laser beam, may be important for usability.
2. The key information transfer characteristics between the activating device and the target object include unidirectional or bidirectional data transfer, maximum data rate, maximum communication distance, which may be different from the maximum distance of activation, and latency in awakening the communication. It should be noted, that the means used for activating the communication channel may be different from the means of communication.
3. The information storage and processing capacity defines to a great extent the capabilities of the target device and thus the potential use of it. The target device may have fixed or dynamic information content, and the amount of information, measured in bits or characters, may vary from one bit to large text files, maps or even program files. The target object may be just an information storage, or it may have processing capability or even "smartness". One further characteristic is the stand-alone or front-end-of-a-system nature of the target object. Typically, a tag of the business card in use case #2 could be a stand-alone target device, while the use case #3 would require a target device with an application interface to the system to be controlled by the UI.
4. The manufacturing cost of the tags is an essential factor as the potential objects to be digitally augmented are numerous i.e. not only traditional digital devices but also other devices, printed commercials, consumer goods, places, things, etc. If the paradigm is aimed to cover the whole range of possibilities, the production cost needs to be rather in the order of cents than tens of cents.
5. The power economy of the tags is another essential feature related to the issues mentioned above at point 4: in the scenario of the world equipped with millions of tags, the maintenance and installation costs easily become a bottleneck. Hence, attention should be paid to minimise the need for battery recharge or change, and preferably other (ambient) power sources should be used.

Other important factors relevant especially for applications in the near future include compliance with standards such as those for RFID (Radio-Frequency Identification) and IrDA, compatibility with existing or future infrastructure, and prevalence and universality of pointing devices.

In the following, we aim to analyse potential implementation alternatives of physical selection in terms of the issues mentioned above and in the light of the three use cases.

4. IMPLEMENTATION ALTERNATIVES

The three main alternatives for implementing physical selection are visual codes, infrared communication and electro-magnetic methods. Wired communication methods are left out, since they require clearly more actions from the user than the physical selection paradigm implies.

4.1 Visual codes

The common barcode is the best known visual code. Barcode is a one-dimensional code consisting of vertical stripes and gaps, which can be read by optical laser scanners or digital cameras. Another type of visual code is a two-dimensional matrix code, typically square shaped and containing a matrix of pixels [7]. Optical Character Recognition (OCR) code consists basically of characters, which can be read by humans and machines.

The introduction of mobile devices with embedded digital cameras has made visual codes a feasible solution for physical selection. A code can be read with the camera and analysed by image recognition software.

Visual tags are naturally suitable for unidirectional communication only, as they are usually printed on a paper or other surface and the data in them can not be changed afterwards [5]. When printed on paper or adhesive tape, the tag is very thin, and it can be attached almost anywhere. The most significant differences between barcode, matrix code and OCR lay in the information density of the tag and the processing power needed to perform the image recognition. Barcodes have typically less than 20 digits or characters, while matrix tags can contain a few hundred characters. The data content of an OCR is limited by the resolution of the reading device (camera) and the available processing power needed for analysing the code. Visual codes do not have any processing capability and they do not contain active components, thus their lifetime is very long and they are inexpensive. The reading distance ranges from contact to around 20 centimetres with hand held readers and it can be up to several meters in the case of a digital camera, depending on the size of

[2] A tag should in this control application support bidirectional communications and also allow control of the device which it is attached to. This may be reached either by use of some advanced technology for tagging (e.g. IrDA) or by a combination of a tag (e.g. RFID) and some other communications mechanism (e.g. Bluetooth). In the latter case the tag would contain the necessary communication parameters to launch the communications in the actual communication channel (BT).

the code and resolution of the camera. By nature, visual codes are closer to the pointing class than the proximity type of selection.

Barcodes are widely used for labelling physical objects everywhere. There are already a myriad of barcode readers, even toys, on the market. Commercial image recognition software is also available.

4.2 Electromagnetic technologies

RFID systems incorporate small modules called *tags* that communicate with a compatible module called a *reader* [3]. The communication is usually based on a magnetic field generated by the reader (inductive coupling), but with very short operating ranges it is also possible to apply capacitive coupling. Operating ranges up to several meters can be achieved by long range RFID tags based on UHF (ultra high frequency) technologies [2]. The tags are typically *passive*, which means that they receive the energy needed for the operation from the electromagnetic field generated by the reader module, eliminating the need for a separate power supply. In addition, there are *active* RFID tags that incorporate a separate power supply for increasing the operating range or data processing capability. RFID technology can be applied for physical selection by integrating a tag in the ambient device and a reader in the mobile device or vice versa.

Typical tags based on inductive coupling incorporate an antenna and one IC (Integrated Circuit) chip providing data transfer, storage and possibly also processing capability. Usually the data transfer is unidirectional from the tag to the reader, but also bidirectional tags exist. The operating range is typically from a few millimetres to several tens of centimetres depending on the antenna, operating frequency, modulation method, operating power and bit rate. Examples of operating frequencies typically used are 125 kHz and 13.56 MHz. Originally the RFID tags were aimed at the electrical labelling of physical objects, replacing visual barcodes. Currently, the RFID technology has established itself in a wide range of applications, e.g. automated vehicle identification, smart cards, access systems and toys. There are several manufacturers providing RFID ICs, tags and systems. The basic advantages of the inductive RFID technology compared to other electromagnetic technologies are low price, small size, operation without a power supply and good commercial availability. These advantages make the inductive RFID technology very attractive from the viewpoint of physical selection applications based on the proximity concept.

In addition to the RFID technologies, there are some technologies based on magnetic induction and particularly aimed for short-range communication. In general, compared to RF (Radio Frequency) based technologies, magnetic induction has some advantages in short-range (below 3 m) wireless communication such as power consumption, interference and security [1]. There are also some commercial components available which are applicable in physical selection applications.

Longer operating ranges than by magnetic induction can be achieved by UHF-based technologies such as Bluetooth, other wireless personal area network (WPAN) technologies and long-range RFID technologies. The operating range of these technologies is typically several meters, which is too long for most of the physical selection applications. However, it is possible e.g. to reduce the operating range by external shielding or to use the received signal strength indication (RSSI) if available. Examples of the operating frequencies of WPANs and long-range RFID tags are 868 MHz, 915 MHz or 2.45 GHz. One possible disadvantage of Bluetooth, concerning especially ambient devices, is the high power consumption. However, the backscattering technology used in the long-range RFID tags enable an operating range up to several meters even without any external power source. Components and modules are available from several manufacturers.

4.3 Infrared technologies

Infrared (IR) is widely used in local data transfer applications such as remote control of home appliances and communication between more sophisticated devices, such as laptops and mobile phones. In the latter case, the IrDA standard is widely accepted and it has a high penetration in PC, mobile phone and PDA environments. Due to the spatial resolution inherent to the IR technology, IR is a potential technology for implementing physical selection applications based on the pointing concept.

An IR tag capable of communicating with a compatible reader module in the mobile device would consist of a power source, an IR transceiver and a microcontroller. The size of the tag depends on the implementation and intended use, but the smallest tags could easily be attached practically anywhere. The data transfer can be unidirectional or bidirectional. The operation range can be several meters, but a free line-of-sight (LOS) is required between the mobile device and the ambient device. In the IrDA standard, the specified maximum data rate is 16 Mbit/s and the guaranteed operating range varies from 0.2 to 5 meters, depending on the used version. One possible problem of IrDA, concerning especially the ambient device, is its high power consumption. For reducing the mean power consumption and thus extending the lifetime of the battery, if used, the IR tags can be woken up by the signal from the reader module [6,9]. It is also possible that the tag wakes up periodically for sending its identification signal to the mobile device in its operating range.

In general, IR technologies are very commonplace. Many home appliances can be controlled by their IR remote controller. Several mobile phones and laptops incorporate an IrDA port, and with suitable software they could act as tag readers. Components and modules are also available from several manufacturers.

4.4 Comparison of the technologies

The three most potential commercial technologies for implementing physical selection are compared in Table 1.

Bluetooth is included for reference since it is the best known local wireless communication technology. Obviously, exact and unambiguous values are impossible to give for many characteristics and this is why qualitative descriptions are used instead of numbers. When a cell in the table has two entries, the more typical, standard or existing one is without parenthesis, and the less typical, non-standard or emerging one is in parenthesis.

In the use case #1 *Updating the context profile of a mobile* device tags are used in a variety of places, usually without easy access to a power supply. To create sufficient infrastructure, a large amount of tags is needed. This suggests that the optimal technical solutions are based on visual codes or RFID tags although the use of infrared tags is also possible.

All suggested technologies apply to the *use case #2*. Several sub-cases of this use-case seem to be easier to use from a distance and that makes visual codes or infrared as a pointing based technology more suitable than electro-magnetic methods. When the premium is on the cost, barcodes seem to be the optimal solution.

The *UI for devices and services without display and keys* use-case #3 is the most demanding of the three cases presented. Bidirectional communication, and a demand for data processing capabilities on the tag side rule out the visual code option. Of the two remaining alternatives, infrared seems to be more compelling because of the standardised bidirectional communication and the ability of the tag to act as a front-end for the device in question.

Table 1. Comparison of potential commercial technologies for physical selection (Bluetooth included as a reference).

	Visual code	IrDA	RFID, inductive	Bluetooth
Selection concept	Proximity/ pointing	pointing	proximity	none
Data transfer type	unidirectional	Bidirectional	unidirectional (bidirect.)	bidirect.
Data rate	medium	high	medium	high
Latency	very short	medium	short	long
Operating range	short-long	medium (long)	short (medium)	medium (long)
Data storage type	fixed	dynamic	fixed (dynamic)	dynamic
Data storage capacity	limited	not limited	limited (not limited)	not limited
Data processing	none	yes	yes, limited	yes
Unit costs	very small	medium	low	medium-high
Power consumption	no	medium	no (low)	medium-high
Interference hazard	no	medium	low-medium	medium-high
Support in PDAs or m-phones	some (camera phones)	yes	no (future phones may have)	some (high-end m-phones)

5. DISCUSSION

Physical selection is a potential paradigm for human computer interaction in the ubiquitous computing domain. After analysing three potential use cases, some important issues related to the requirements of implementing physical selection could be identified. These are the principal way of selection - proximity or pointing; information transfer characteristics - unidirectional vs. bidirectional, data rate and latency; information storage and processing capacity; manufacturing costs and power economy. Furthermore, conformity with standards and existing infra structure are of importance.

Three implementation methods, namely visual codes, electro-magnetic means and infrared technology offer suitable characteristics for different applications. For example, visual codes are best suited for cases where cost critical unidirectional pointing type selection is needed, whereas RFID tags are best suited for unidirectional proximity based use cases. Infrared lends itself naturally for pointing based bidirectional control applications.

The physical selection paradigm seems well suited for cases where the user is on the move and uses a mobile device, such as a PDA or a smart mobile phone, for interacting with the digitally augmented environment. The vast and ever growing number of smart mobile devices with local communication capabilities, such as IrDA, Bluetooth, cameras for visual code reading, and in the future also RFID based techniques, offers a technical basis for this new paradigm. The simultaneous proliferation of low-cost tags makes the paradigm even more tempting.

We will continue our research on issues like the implementation of physical selection (IrDA and RFID based), usability, and identification of applications benefiting from this paradigm.

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