Smartphones to Access Hybrid Information Spaces

Spyros Veronikis, Kyriaki Zoutsou, Giannis Tsakonas and Christos Papatheodorou

Database and Information Systems Research Group

Department of Archive and Library Sciences,
Ionian University.
Corfu, GR-49100, Greece.
Phone: +30.26610.87419

Email: {spver, gtsak, papatheodor}@ionio.gr, k.zoutsou@gmail.com

Abstract

This chapter presents how mobile phones nowadays can be used as a handy and always around medium to interact with information collections of both physical and electronic form. It presents their evolution into powerful computing devices capable of communicating with other computing infrastructures, like the World Wide Web, and assisting them in finding the information of interest in the most convenient form, right when the need arises. It also provides a description of the current interaction modes between users, devices and information objects as well as some examples of first and second-generation mobile services. Furthermore, the authors hope that understanding the potential introduced by mobile phones in the modern information landscape can bring some insight to new information seeking strategies, that enhance exploration and not just querying. This understanding can be used to create new, innovative and novel services to enhance the seeking experience while interacting with hybrid information spaces.

INTRODUCTION

The total number of mobile phone users in the world is currently estimated at 3.3 billion, accounting for nearly 50% of the population on Earth (Reuters, 2007). Nearly 90% of the world's population is expected to be using mobile phone services by 2010. As broadband wireless communications become available, voice telephony is at the same time converging with electronic services. This integration enables mobile phones to access a range of data services. On the other hand, computer evolution and electronic publishing created a wealth of information, available in electronic form. In the mid 90s, the advances in computer networking technology made the Web and the Internet a new medium to distribute electronic content and access content which was not locally held. The success of Internet led to the creation of on-line resources, like magazines and web pages, as well as the wider use of digital libraries and other collections that were universally accessible. The new resources strongly affected the users' seeking behaviour and strategies. As a result, nowadays there is a strong demand for advanced searching and browsing in diverse sources of information, which enhances its completeness, validity and currency.

The need to access electronic sources, anytime available, combined with the potential raised by the wide spread of mobile phones, which can be used as terminals to receive electronic information in almost anyplace, has been recognized worldwide. Mobile Computing (MC) is a term to describe the ability of using anywhere a portable computing device by means of wireless or wireline communications. This chapter focuses on utilizing MC in hybrid information spaces, i.e. environments that hold information both in physical and electronic form. Mobile interaction with hybrid spaces can be applied in areas such as advertising, tourism and museum guides, peer-to-peer
information sharing and remote control of public resources, like printers and displays.

In the rest of the chapter we describe the usage of portable computing devices as a means of interaction with physical and digital spaces. We first provide some background information on smartphones, on the challenges of mobile computing and an overview of a web-based architecture. We then discuss interaction issues with the device and describe their usage in hybrid spaces. Finally we outline the future trends and conclusions.

BACKGROUND: Smartphones and mobile computing

Apple released the first personal digital assistant (PDA) in 1993 and it was a pocket-sized mobile device used for Personal Information Management (PIM). Typical applications included were calendar, address book, calculator, world-clock and note pad. At the same time, IBM released Simon, the first smartphone, which besides PIM functionalities could support mobile telephony and SMS texts over 2G digital cellular telephony networks. In 1995 infrared and wire-line serial communication with nearby devices was implemented as an alternative for data exchange and synchronization. In addition, smartphones could connect to proxies and join other computer networks to retrieve data such as e-mail. The need to transfer quickly and display bigger amounts of data led to faster communication protocols (Bluetooth, EDGE) and 3G telephony networks in early 2000. At that time, cameras and colourful screens were considered standard equipment. By 2005, many smartphones were enabled with open operating systems, rapid transfer protocols (WiFi, USB), touch screens, and solid-state memory cards. Besides telephony, they could support web browsing/email, instant messaging, document viewers and multimedia playback. Nowadays, smartphones are equipped with GPS receivers, multi-touch screens and advanced interaction modalities, such as handwriting recognition and proximity sensing. Smartphones have evolved into powerful communication and computing devices capable of collecting and processing data, anytime/anywhere, and seem to become a universal mobile terminal for communication, control, entertainment and location-based services.

Smartphones’ increasing popularity and current computational capabilities meet the mobile application requirements and they compare well against other portable devices, such as PDAs and laptops. However, mobile computing introduces new challenges and constraints, inherent to mobility. Forman and Zahorjan (1994) classify them in three major categories; wireless communication, mobility and portability. Mobile connectivity can be highly variable in performance and reliability due to heterogeneous networking, disconnections, available bandwidth and security risks. Furthermore, the frequently changing location of the device, widely known as roaming, forces it to change its identification number and tracking it down might be considered as privacy violation. Mobility is inherently hazardous since the device might be stolen, damaged or lost. Also, a portable device must depend on a finite energy source, needs to be lightweight, small and durable, and therefore it is resource-poor compared to a desktop device.

![Figure 1. Two alternative communication paths to access data repositories with a smartphone](image-url)
However, when using handhelds indoors, in closed and controlled environments, such as exhibitions and libraries, and for short information provision, many of the above mentioned issues are easier to handle. Smartphones can join a single network available, usually a WLAN, which offers full coverage, broadband connections and low traffic due to the limited number of connection requests in the area. Figure 1 shows the two communication modes available in a smartphone, which the user may choose depending on signal strength, cost and speed. Communication through a circuit-switched network is usually much slower and expensive but available almost anywhere and more secure. To reduce security risks, data exchange with the wireless network can be encrypted with a key, and have connection closed after some period of idle time. There is no issue on privacy violation because of user tracking, since users move in a certain public area anyway, exactly as regular visitors. Devices are unlikely to be stolen because of the presence of security or institution's personnel. The small user interface of smartphones makes user interaction with the device cumbersome, but as long as the information exchanged is short, people are willing to tolerate the inconvenience for the benefit of added-value services. To support users in their tasks, nearby resources such as info-kiosks, computer rooms, printers and displays can provide features and services not available by the user's device. Regarding user tracking, we note that precisely extracting the user location inside a building is not an easy task. Most Global Positioning System (GPS) receivers cannot detect satellite signals to inform the user of his location. Hightower and Boriello (2001) developed a taxonomy of several location-sensing techniques for indoor and outdoor applications.

The wide adoption of the Internet and the World Wide Web, the industry trend in the deployment of web services technology and the evolution of mobile phones to support data exchange, make smartphones ideal for interacting with hybrid information spaces. The CoolTown project (Kindberg et al., 2000) explores the opportunities of using a handheld device to interact with objects, people and places that have a web presence in the WWW. Among several technologies, service oriented architectures (SOAs) are mostly created by using web services. This architecture enhances interoperability since any device capable of running client application software, qualifies. It contains three major components; discovery, description and messaging (Hirsch, Kemp and Ilkka, 2006, p.22). Service providers, such as web servers, must be discovered prior to using the service. Several mechanisms can be used, like sensing or scanning as described above. Alternatively, indirect mechanisms can be used, such as service lists or directories on a web page. Once a service has been detected, the device needs to know which protocols to use for data exchange, how to structure messages and which security or other policies to observe. Web Service Description Language (WSDL) is used to create structured documents that describe the services. These XML-based messages are wirelessly exchanged according to the SOAP protocol, usually over HTTP/HTTPS.

These processes (discovery, description and messaging) are performed in a 3-tier architecture, namely Presentation, Logic (or application) and Data. At the presentation tier the interface (web browser) of the smartphone receives an input from the user or a smart object. The request is processed in the logic tier by the application server which queries the database management system at the data tier and retrieves the necessary information. The extracted data are sent back to the middle tier where they are properly formed by the web server and passed through the presentation tier to the software client in the user's device. Such architectures ensure anywhere/anytime accessibility and therefore are appropriate for the development of mobile information services.

INTERACTING WITH SMARTPHONES

To interact with the user, smartphones provide a user interface similar to Windows, Icons, Menus and a Pointing device (WIMP). Applications run on separate windows, but because of the small screen size, usually only one window is shown at a time, with the rest being minimized. A stylus and a touch screen can be used to make selections from menus, and special purpose commands can be invoked by tapping on corresponding icons. A joystick and special purpose buttons allow for
thumb operation of the device. The user can enter some text, by means of a small keyboard that can be numeric, virtual, full or a slide-out QWERTY. Some models also support handwriting recognition for faster and more natural input.

Rukzio (2006) proposed a taxonomy of mobile interaction regarding basic concepts, like sensed property, number of dimensions, direct or indirect interaction, and relative or absolute commands. They refer to either human-computer interaction or interaction with objects that, when prompted, can send electronic information to the device. Hence five interaction categories exist: (a) **Touching** is the interaction technique where the device comes very close or touches the object to trigger a short data exchange session. It requires some sort of contact mechanism or a proximity sensor. (b) **Pointing** is a technique according to which the user points his device to the object in order to retrieve some information, as in the case of infrared connections. (c) **Scanning** is an interaction technique that uses wireless signals and protocols, such as Bluetooth, to search for nearby available resources or services. Once a strong signal is detected, a connection is established and the device exchanges data with the resource. (d) **User-mediated object selection** is an indirect interaction technique between the device and physical objects. The smartphone cannot identify on its own the physical object in the environment. Instead, the user types in some information provided by the object, such as its call number or a URL, to establish a link between them. (e) **Indirect remote control** is an extension of conventional interaction techniques that uses the smartphone's joystick, stylus or keypad, to take control of physical objects, such as public displays. However, there are some interaction barriers such as the small screen size that raises presentation issues, the small keyboard that makes input of long texts cumbersome and the battery life that allows for some hours of operation.

Mobile devices have been used in rich information environments such as large museums, to offer added-value information services, like audio descriptions of artefacts in visitor's native language. Nowadays, smartphones support multimedia playback and wireless connections with nearby computers that serve electronic information, such as info-kiosks, beam stations and web servers. This information provision is particularly important in areas where the objects themselves are not self-explanatory and there is no space available for conventional labels or interpretations. It can be applied in commerce, using advertising posters and interactive display cases, in museums, in libraries and in exhibitions (Rukzio, 2006). An example of such an one-way interaction is the case of a user who photographs a quick response code (QRC), holding information about the bus schedule (time and routes) at a bus station instead of copying it by hand (Liu, Doermann & Li, 2006). The data is transferred to the smartphone and interpreted to something the user can understand, i.e. a short text. In cases that the information quantity is too much to be stored on a visual code, it is usually stored in an HTML document, which can be accessed by a web client running on the smartphone. The visual code only needs to hold the URL of the HTML document.

Moreover a smartphone can assist its user in navigation and provide valuable guiding instructions (Baus, Cheverst and Kray, 2005). GPS-enabled devices and maps that depict floor plans generally support navigation in the physical space. The user can set a destination (point, object or room) or have superimposed on the map items of special interest, as in the case of personal guided tours in museums. Additionally, navigation aids like structured data schemes, such as thematic directories, headers, previous and next page commands and links to other information topics, can help the user browse the intangible space of electronic information. A similar case in a library setting is described in the following scenario; a new visitor accesses the web interface of a library catalogue to search for a book. From its metadata, she ensures it is available and passes its location to a map application running on her smartphone. She follows the instructions of the device to find the book (Aittola, Ryhänen & Ojala, 2003).

SMARTPHONES IN HYBRID INFORMATION SPACES

A hybrid information space is an environment that holds information material in both physical and electronic form. The user can directly interact with books, artefacts, etc in the physical space and also use a computer terminal to access electronic sources of information (texts, multimedia files),
held locally or remotely, by means of computer networks such as the Internet. An interface on the terminal allows the user to interact with the electronic portion of the hybrid space. Nowadays, academic libraries are representative examples of hybrid information space, since they hold information in book repositories (physical) and digital libraries. Figure 2 shows the search interface of a prototype developed at Ionian University\(^1\) to support users in searching the library’s collections. The search results are displayed on the screen and the user can select a retrieved record to see its metadata (e.g. author, subject area, classification number, availability, location, etc). Floor maps available for reference can help users in locating the books in the library. In addition, several document viewers (e.g. PDF, DOC) are used to display the summaries and full-text of electronic files, retrieved from the digital collections. This prototype was evaluated in regard to the user acceptance and satisfaction (Veronikis, Zoutsou & Papatheodorou, 2007) and the results were encouraging. The ability to access information anytime/anywhere and to transfer it either by saving or by emailing it was strongly acknowledged. New library visitors considered the navigation aids quite useful.

To enhance the user’s experience of interaction with the hybrid space, the device operates as a bridge that connects the physical and electronic spaces, and therefore must interact with the items of interest as well. For example, the user can retrieve a detailed description of an object by pointing the smartphone to an infrared beacon, or using the built-in camera to photograph a visual code, which is then interpreted by the device. Alternatively, the device can scan the environment to detect nearby smart objects that broadcast wireless signals containing their call number. Another approach is using the phone to touch an object. It is very convenient when the objects of interest are near the user, such as exhibition items. Want et al. (1999) presented a prototype, which incorporates RFID tags into objects and an RFID reader on the device. Dominant companies in the mobile phone arena, such as Nokia, Philips, Benq-Siemens, NTTDoCoMo, and Sony have also built several prototypes to study the use of RFID tags and other proximity sensors for touching, sensing and near-field-communications (NFC). When sensing a nearby object, the mobile phone retrieves its ID number and establishes a connection with a database or other electronic source of information to retrieve related data and display them on the screen.

Thanks to the advanced technological and communication characteristics of mobile devices new services have been developed which enhance the user interaction with hybrid information spaces. This two-way communication involves the iterative data exchange between the user and three components; (a) the user’s device, (b) the physical object/person/place and (c) a web-based application that retrieves relevant information from the digital space.

Kulfik et al. (2007) present an augmented museum visitor's guide, which provides context-aware services to support person-to-person and person-to-system communication, thus enabling users to share the experience and knowledge of other visitors. By sending direct messages to other users or leaving a virtual “post-it” message for others to see, a user can help other visitors and provide recommendations to make the most out of their visit to the hybrid environment. The system uses contextual information, such as user’s locations, profiles and history of interactions with exhibits, to

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\(^1\) Dept. of Archives and Library Sciences, Digital Libraries and Electronic Publishing Lab (http://dlib.ionio.gr)

Figure 2. A web form interface to search in library’s collections
interpret the messages and deliver them accordingly.

Yatani, Onuma, Sugimoto and Kusunoki (2004) discuss on the usage of PDAs in museums to support collaborative learning. Children use the handhelds to extract information from the physical space in order to solve puzzles and provide answers to the questions posed on the screen. In addition, an HTML document is used to inform the users of the handhelds about their path and interaction history, during their visit in the hybrid space. The document can be reviewed in a desktop workstation later at home.

Besides ad-hoc interaction, web services can combine a desktop PC at home/office and the portable computing device. Krüger et al. (2004) present an approach to a personalized navigation service that interconnects specialized user interfaces for desktop PCs, in-car and on-foot use. The portable navigation system enables the traveller to plan his trip from the PC at home, to choose personalized events of interest at certain locations and to retrieve further data, such as the weather conditions. All this information is stored in a travel itinerary and migrated to his personal handheld, where it can be available whether in car, on-foot or inside other buildings. Krumm and Horvitz (2007) create driver destination models by acquiring GPS data in order to predict the user's destination and notify the user by triggering alerts and recommendations about traffic.

First generation applications of smartphones such as mobile telephony, SMS/MMS, Instant messaging, PIM, e-mail and web browsing, positioning, navigation assistance, data synchronization, and information push-services are mostly extensions of PDA and cell phone functionalities. However, in recent years, second generation applications start to emerge as a result of advancements in mobile computing, wireless networks and proximity sensors.

Smartphones are used for mobile transactions and payments conducted through communication networks that interface with wireless devices (Hu et al, 2004). For example a smartphone can be used to check a bank account and perform transfers regardless of time and location of transaction. It can also be used as an electronic wallet, where an SMS sent to a subscription service will charge the owner’s phone bill for the product purchased (e.g. a bus ticket). Smartphones can also be used to buy products from vending machines or grant access to restricted areas by transmitting owner’s identification and charging data by means of proximity sensors.

Another promising field for smartphone application services is E-health where apart from patient-profiles and clinical history the devices can keep and access information about prescriptions, medicine administration, and in-home patient monitoring (Chan et al, 2008). For example, eHIT (http://www.ehit.fi) developed a system that uses a smartphone, which communicates with data loggers and databases to deliver round-the-clock vital measurements, such as body temperature, blood pressure and glucose levels.

Raento et al. (2005) present a platform for context-aware mobile applications, such as social networking. Users use their devices to discover and communicate with nearby people having similar interests. In addition, they can submit or read previously posted, geo-referenced comments and share pictures of locations or other content. Data is exchanged via SMS, instant messaging, RSS or a social networking web service like Jaiku2 and Twitter3.

FUTURE TRENDS AND CONCLUSION

Next generation mobile networks are expected to converge into a ubiquitous architecture, which includes broadband cellular networks, wireless local networks (WLANs), mobile ad-hoc networks, etc. In addition, personal communication devices are expected to be as common as a wristwatch, connecting to distributed-computing systems, exchanging data with local or remote computers and sensor networks. Next generation interfaces will enable multimodal interaction with the user, i.e. speech and gesture recognition, and with smart objects by means of sensing technologies, such as RFID. Many objects, places and events of particular interest will have an associated electronic description, available anytime/anywhere. Furthermore, services will be personalized and context-aware (Chen & Kotz, 2000), meeting the users' particular interests and taking into account their

2 http://www.jaiku.com
3 http://twitter.com
preferences, location, nearby resources or people, social situation, network connectivity, available bandwidth, time of day, lighting conditions and noise levels.

As we have seen mobile phones are becoming a ubiquitous computing device used anywhere. Additionally, the WWW interconnects billions of electronic information sources, enabling users with additional information. The devices can be used as information harvesting tools that collect data from the physical space, process them, and subsequently retrieve related electronic data. In turn, this process may start a new interaction cycle. New added-value services can be designed to exploit this interaction, offering opportunities for exploration in hybrid environments, information access and delivery and collaborative activities. However, in order to create usable and effective mobile systems and services for multimedia content delivery, developers have to address new issues and challenges that arise from the user interaction with a hybrid world, such as the selection of proper content and methods to deliver it, its presentation and the most suitable interaction mode.

ACKNOWLEDGEMENTS

This work is part of the research project PENED which is co-financed by E.U.-European Social Fund (80%) and the Greek Ministry of Development-GSRT (20%).

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KEY TERMS AND DEFINITIONS

Global Positioning System (GPS): is the satellite-based positioning technology that allows a GPS receiver to identify its location anywhere on Earth. GPS receivers can be found as handheld devices, installed in automobiles for navigational aids, and as modules that attach to PDAs, such as a PalmPilot.

Human-Computer Interaction: HCI (or CHI) is the scientific area of computer science that studies the design, development and evaluation of interactive systems. HCI uses guidelines and evaluation methods in order to support the design of usable and user adapted computing systems with improved interaction.

Hybrid Space: refers to physical places that support or integrate electronic information delivery. This kind of information delivery may be realized through the provision of physical infrastructure that allow information access, such as computer workstations or info-kiosks, and/or through support of users’ mobile devices, usually through some kind of wireless networking. Typical examples include cultural heritage institutions, like museums and galleries, historic monuments, like archaeological sites, and knowledge institutions, like libraries and archives.

Location Dependent Service (LDS): is a context-aware service that adapts itself, depending on user's physical location. LDS is based on the transmission of geographic location information to mobile devices in the same context. Each mobile device can request an LDS and attach geographic location information in order to receive the service.

Near-field communication (NFC): is a standards-based, short-range wireless connectivity technology that enables simple and safe two-way interactions among electronic devices, operating in the 13.56 MHz frequency range, over a typical distance of a few centimetres. Interactions are initiated when special purpose tags (RFIDs) are detected by an appropriate scanner.

Recommender systems: they use information filtering (IF) techniques attempting to present information items (movies, music, books, news, web pages) that are likely of interest to the user. Typically, a recommender system compares the user's profile to some reference characteristics. These characteristics may be from the information item (the content-based approach) or the user's social environment (the collaborative filtering approach).

RFID (Radio Frequency Identification): is an identification method, relying on storing and
remotely retrieving short data using devices called “RFID tags” and “transponders”. The tag, also known as electronic label, keeps the data (e.g. serial number of an object), which can be retrieved by the transponder (via radio signals) when it comes close to the tag. Unlike barcodes there is no need for line of sight to the scanner and identification is many times faster.

**Smartphone:** is a mobile phone with advanced capabilities, offering PC-like functionality. It provides digital voice service, as well as text messaging, Web access, still and video camera, audio and video streaming and PIM organizer. Late models integrate GPS receiver, mutli-touch screens, proximity and accelerometer sensors. Compared to PDAs they usually have smaller screens and keypads instead of virtual keyboards and smaller memory capacity. However, late smartphone models such as the iPhone (by Apple) indicate that the distinction between PDAs and smartphones are converging into one device.

**WiFi:** is the colloquial name for the IEEE802.11 data protocol used to transmit data wirelessly over short distances. WiFi networks have become extremely popular, revolutionising the networking scene over the past five years. Many hotels now offer WiFi access for travelling businesspeople.