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A TAXONOMY OF MOBILITY: SOME IMPLICATIONS AND REQUIREMENTS FOR MOBILE INFORMATION APPLIANCES

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Abstract: *The term mobility can be understood from different perspectives: from the technological point of view, through information, to people. Because of this wide acceptance, it was hard to provide a wider and more unified categorisation of all aspects involved in mobility. Even so, this paper proposes to introduce the taxonomy of mobility. The taxonomy consisted of three independent components from the user perspective: the mobility of people; the mobility of infrastructure and the mobility of information. The paper analyses the three dimensions and presents the implications of mobility in all aspects of life. The papers concludes with some remarks and a list of requirements for mobility of information appliances*

Keywords: *mobility, interaction, user interfaces, applications, information appliance*

1 INTRODUCTION

Mobility could be defined as the quality or the state of being mobile [1]. Based on this definition, the classification for the term mobility is broad as it covers the majority of things that move. Because of this wide acceptance, it was hard to provide a wider and more unified categorisation of all aspects involved in mobility. Even so, a narrow classification is proposed, having the epicentre in the mobility of the Information Appliances (IA) from the point of view of the User Interface (UI). Based on this classification, a set of requirements for the UI has been extracted and is presented in the last part of this paper. The proposed categorisation is the result of combining several papers (probably the most complete work was done by Rodden and co-authors [2]) that described or defined mobility from both telecommunication and Human Computer Interface (HCI) perspectives. However, the main topic was the UIs and their requirements when used by a mobile IA.

When analysed from the point of view of the data, some groups have categorised mobility as having three separate components: users, computers and information (from a database point of view [3]). From the user perspective, the mobility splits into three separate components: mobility of people, infrastructure and information. These components are independent and each can be again split into sub-components. For example: users, devices and applications.

2 THE TAXONOMY OF MOBILITY

Table 1 summarises and describes a taxonomy of these three independent components. The categories proposed do not cover all possible aspects of mobility (e.g., social implications of mobility in families, generations or groups/clans). In the proposed approach, the focus was mainly on UIs and their collateral implications (as in infrastructure, information and users).

Table 1: Taxonomy of mobility from User Interfaces perspectives.

Category	Subcategories	Correlated matters
People	Individual	Work
		Leisure
		…
	Group	Friends
		Colleagues
		…
	Organization	Companies
		Societies
		…
	Nation	…
Infrastructure	Information Appliance/Terminal	Free
		Embedded
		Pervasive
	Network	Link (i.e., mobile IP, GSM, WiFi...)
		PAN
		LAN
		WAN
	…	…
Information	Application	Code
		Data
		RPC
		…
	Service	Location
		People
		Infrastructure
		…

The following sections detail each of the cells in the table, adding some extra dimensions to some specific components.

2.1 Mobility of People

The mobility of people can be divided as mobility of individuals, groups, organizations and nations and it could be extended to larger groups. What is important is to notice that each of the categories is somehow independent. While individuals are part of a group, in terms of mobility from the UIs perspective, they are a special category. Individuals can access the information in different ways, but when they are in a group, they could act together or even use the same UI (e.g., a mobile projective display).

The mobility of individuals could embrace different aspects. From an activity point of view, it could be a leisure or work activity related mobility, and each aspect could come with more ramifications.

Group mobility could also embrace different aspects, depending on the interests of the individuals or the rules of the group. It could include family, colleagues, teams and other common interest clusters. What is important to notice is that, from UIs perspective, groups represent another dimension of interactions that the mobility embraces. The users can share documents, share infrastructure, communicate, integrate, and develop together using as much as possible of a common environment. The UIs should be adaptable and aware of the individual preferences within the group in order to support this special interaction. Moreover, the mobile aspect adds more dynamics to the concepts of a group, considering the privacy and security of a user while in a group (notice the clear separation between individual interests and the group interests).

A larger form of clustering of individuals is in organizations. This involves a more ordered type of interaction. It could also include inter and extra-organizational levels of mobility. While the grouping could be around common interests, the organization could include common rules, infrastructure and services that are available to the users. From the mobility perspective, this category concerns the maintenance and structure of mobile resources and the capabilities to adapt to changes (mainly of a geographic nature).

When looking at an individual and his/her determination to be mobile, the classification of mobility was split [4] into three components: navigation, sojourn and promenade. Another important component was work-oriented activities (mobile work, emergency work, field of combat). This concluded the splitting of the term mobility based on the scope of the motion to four components as is described in **Table 2**.

Table 2: Classification of mobility from user's motivation to move perspective.

Applies to:	Motivation
Individual	Navigation (the user is involved in travel activities and needs assistance)
	Sojourn (the user resides temporary at a different location, as a leisure visitor or on a work trip)
	Promenade (the user is missing a specific destination)
	Work (the user is having a task that by nature is mobile–commonly defined as mobile work)

The need for mobility comes from various contexts in which the user is moving. These contexts could be travelling as a tourist [5-7] or navigating outdoors in a city [8]; it could also support indoor navigation [9] or outside office activities [10].

2.2 *Mobility of Infrastructure*

This mobility does not only refer to the ability of people to move, but also how they are able to use the infrastructure while being mobile. Infrastructure supporting mobility and the mobility of infrastructure are probably the most common subjects for the research in mobility. Parts of the infrastructure are the devices and the networks interconnecting them.

A good approach in classifying devices was introduced by Rodden and co-authors [2]. In their paper, based on their capabilities to exchange information and other resources with the environment they split the devices into three categories: *free, embedded* and *pervasive* (**Table 3**).

Table 3: Mobile devices and devices supporting mobility classification based on their information and resources exchange.

Applies to:	Type of exchange
Device	Free (the device is independent)
	Embedded (the device is enclosed in another device or environment)
	Pervasive (the device functionality is spread through the environment)

A proposed classification is based on the classes of devices and how they are used. **Table 4** details this classification. Some of the fields of the classification are dependent. For example, a wearable device could also access remote resources. The classification proposed here tries to cover all the possible cases of usage found in the literature and in practice, and hence it did not seek the classification based on independent terms.

Table 4: Mobile device classified by usage of device.

Applies to:	Usage
Device	Wearable (the device is worn on user body)
	Remote (the device is a communication device that accesses remote resources)
	Portable (the device can be moved but is not small enough to fit in the hand, more like a laptop)
	Handheld or micro-mobility (the device is an information devices like a PDA that can be held in the hand)
	Ubiquitous (the devices are invisible to a user but they assist the user in mobile activities)

The proposed classification can be classified by the one suggested by Rodden and co-authors by including the classes from **Table 4** as follows: *wearable*, *remote*, *mobile* and *handheld* could belong to the *free* category of **Table 3**; *ubiquitous* could belong to *pervasive*; while *remote* and *handheld* or *micro-mobility* could be also included in the *embedded* category. Rodden's proposed taxonomy is more generic and therefore, it has been included as such in **Table 1**. The taxonomy proposed here is more empirical and hence more specific.

Some have argued that the mobility of the activities should be included in the classification [4] as there might be some cases where the mobile device is used in a static activity (**Table 5**). However, these are just specific cases and they are only relevant when some classes of interfaces are not operable in a dynamic activity (like writing an email from a laptop while walking on a street).

Table 5: Classification of mobile devices based on their activities.

Applies to:	Type of activity
Activities	Dynamic (the user is moving while using the mobile device)
	Static (the user is fixed while using the mobile device)

Because of the abundance of contexts in which these mobile activities occur, a device could track the attributes or context in which it is used and change accordingly. When a device is context aware (a good example is available in the Hinckley and co-authors [11]), it could help to tailor the applications for mobile devices. Moreover, it could benefit from the special nature of the context in which the user is operating it, e.g., navigation.

While the devices are an important part of the infrastructure and the closest category to the subject of this thesis, the network contributes to many of the functions used by the devices.

From the mobility point of view of the UI, the network component could be split into levels of topological access to remote resources. They could be near the user (Personal Area Network or PAN) evolving through a Local Area Network (LAN or Intranet) and a Wide Area Network (WAN or Internet). Another important component would be the link or the protocol and how well it could support mobility (there might be problems like optimal routing, handover support or roaming). Sometimes, not only the logical part of the network infrastructure would be mobile but also the physical part could become mobile (as in satellite network coverage).

2.3 Mobility of Information

This mobility is about accessing information by people, anytime (sic), anywhere [12]. The last category defining mobility is, therefore, the mobility of information and is another category that is close to the topic of this work.

The mobility of information could be split in two categories, applications and services, based on their support for mobility and the location of the information. The mobility of applications means the ability of an application to work in a mobile environment (in other words, to support mobility) while the mobility of services is how the applications provided by service providers are accessible from a mobile environment.

Applications are defined as computer programs designed for a specific task [1]. Mobile applications are, therefore, computer programs designed that they are accessible or operable from a mobile platform. This means that the code and data should be either available or capable of executing on a mobile platform or should be accessible from a mobile platform while located on a remote computer. A more exhaustive description can be found in the Fuggetta and co-authors paper [13] that examined code mobility from the point of view of the programmer. Heuer and Lubinski, on the other hand, looked into data mobility and how to access databases from mobile environments [3].

Services could be defined as activities performed by one party for the benefit of another. From the mobility perspective, services are applications that run on a remote location and are used from a mobile environment. Due to the mobility of data and code, and generally, the distribution of resources in a mobile environment, it is hard to distinguish between mobile services and applications. In the approach here, service is a group of applications that reside on local or remote locations and contribute to a common activity. There are infrastructure services that support the infrastructure but they are not so important from the point of view of the UI (they should be invisible to the user). There are also personal services that enhance a user’s personal experiences. Another important group of services for these studies were location based services.

Personal services deal with a user’s personal interests. They could handle incoming calls (like call waiting) or they could provide access to data (calendar, office applications). Parts of the personal services interact with location based services, particularly the context-aware data gathered through these services. Probably the most challenging research is the one to study privacy protection and anonymity of the user when using personal and location services due to the amount of data gathered on user’s preferences and customs.

Location based services are a group of services that are aware of the geographical position of the user and provide more specific output to the user. Sometimes, knowledge of the location of the user is not sufficient and combinations of other sources of information (like user preferences, type of user’s activity or the time) contribute to better access to service resources [14].

Giaglis, Kourouthanassis and Tsamakos [14] classify location based services as: *emergency*, *navigation*, *information*, *advertising*, *tracking* and *billing services*.

Emergency services deal with emergency calls and how to handle the situation (sometimes having to reveal automatically the location of the user).

Navigation services provide a user with fast routes, traffic information, indoor and outdoor directions.

Another location based service is the *information services* that could provide a user with important information on various sources of data like yellow pages, travel services or even infotainment.

Advertising services are another part of location based services that contribute to better information access on products or other services from specific locations. They could include alerts, advertisements, banners and guides.

Another important part of location based services is the *location sensitive* billing *services* that could facilitate mobile commerce combining the location with a purchase (it adds a new dimension to advertising).

While this classification was quite broad, Gialis and co-authors failed to take into consideration other categories than individual users. Even services for individual users should support other activities than leisure time activities. For example, services to support work-related activities, like sharing of resources, or services supporting mobile engineering. Some work-related location based services include support for a person working on maintenance [15-17] or inspection [18, 19]. These services require infrastructure support and special settings. They could be classified as belonging to both emergency services (if the work is related to emergency situations) as well as information services (as work related information sharing and access) without necessarily being either of them. Because of the importance and the number of services related to work, the classification should include *mobile work services* as another class. These services should support the tasks of a mobile worker in outdoor and indoor locations, and they should be concerned with security and reliability along with services supporting collaboration, sharing and accessing of resources.

2.4 Mobility and User Interfaces

While previous sections defined the mobility from a broader perspective, this section analyses the implications of mobility on UIs. The UIs for IAs (cf., definitions from page **Error! Bookmark not defined.**) have a long history of design, starting with the old 1950 batch mode cards with punched-holes, to the more advanced graphical UI (GUI) or even the "post WIMP[1] GUI" of the future [20]. Throughout history, these devices have all been static. They were on large shelves in computer rooms or on the desk and difficult to operate on the move. The challenges of today are to make these IAs mobile, and similar to any IA, mobile devices need a UI. Unlike the UI of desktop computers, those for mobile ones have the special requirement as to be operable while the user is mobile. A mobile IA should be able to provide similar resources as a fixed or desktop computer, with the additional quality that it could operate while a user is mobile. Even so, the abilities to unbind the links that keep IAs fixed are hard to break. The current approach in designing UIs for mobile IAs are concerned mostly with the emulation of the functions available for a desktop computer. So far, very few researchers have been emphasising the mobile aspect of the interaction when using mobile devices. Some even argue that mobility is not always necessary and that a system, even though designed to be mobile, could eventually be used as a fixed one [12]. However, the wave of support for various types of mobility should lead to important changes on how input and output for these devices are being designed and built [21]. While mobility and interaction when mobile are important, the context in which mobile devices are used is also relevant. In general, it is safe to say that the user's privacy is critical, but in certain contexts, the infrastructure should also allow a certain level of proximity or location information to the system. In certain aspects of mobility (like mobile workers) the information on possible disconnections from the network takes precedence over privacy. Failing to do so could induce dangerous consequences on how data is interpreted and reacted to it in special situations like safety critical fieldwork [2]. Mobile interfaces should provide, in case of

[1] WIMP means Windows, Icons, Menus and a Pointing device, typically a mouse. WIMP GUI is the class of graphic UIs that current operating desktop computers are using.

an error or disconnection, information to others in a group, hence enabling them to access the resources properly.

Even though recent technological advances have reduced the size of system components, and even after incorporating latest developments in the field of mobile IAs, the interfaces and the design patterns being used are still paradigms from desktop computers that are not suited for the mobile environment [22, 23]. For example, while in desktop computers a user can handle the interactions quite naturally in front of a big monitor and tabletop keyboard, mobile devices are bound to small screens [24] and little keypads. Many approaches have been made to resolve these issues: audio, voice and facial recognition enhance the experience of a mobile user; various sensors also contribute to a better context and location awareness; augmented and Mixed Reality (MR) increase the information availability and the way it is represented. Combining all these technologies could generate a wider range of implementations and development for these types of devices in the future.

2.5 Mobility Requirements for User Interfaces

Information appliances when becoming mobile require certain tailoring in the design, especially knowing that mobility usually means that the size of the devices will decrease. Unfortunately, becoming smaller also requires that the screen is smaller. With smaller screens, even if using enhancements like sound [24], interaction could become difficult. From this perspective, the first and most important requirement is to extend the screen size.

Desktop computers, due to their nature, were merely concerned with desk activities. These activities are involved mostly with work related tasks, but entertainment and games applications have also been available. Mobile devices, on the other hand, are free of such a strict limitation. They have the potential of reaching a larger segment of the population that is not bound to a fixed environment, like the desk. As a result, an analysis of usability requirements of the UIs for mobility is important and needs consideration. The definition of usability given by Nielsen [25] described it as being about: learnabilty, efficiency, memorability, errors and satisfaction. Taking the context in which they are used [26], the UI design of a mobile device should consider the following aspects: *networking*, *mobile vs portable*, *lightweight*, *ergonomic* and *non-intrusive*.

The *networking* property of a mobile UI refers to the quality of accessing remote information and resources. Remote access of information also necessitates a certain security level for the communications. Even though this requirement concerns the infrastructure, remote access of information and the ability to interface with other devices is important for a mobile device [27].

The *mobile vs portable* aspect refers to the capability of a UI to operate while a user is in motion. It is difficult to operate a desktop computer, even if it could be moved, (like a portable/laptop computer) while walking or driving.

The *lightweight* attribute concerns the device and how the interface operates from the point of view of weight. A heavy device would cause weariness to a user and could lead to abandonment when long tasks need to be carried out.

Due to the situation in which mobile IAs operate, their UI design should also concern the *non-intrusive* aspect of the interaction. A UI that will block, distract or scare a user while driving could cause accidents. Moreover, knowing that mobile devices should assist a user during various activities at work and during leisure time, they should include some personalization features. The requirement for more personalization in mobile devices could handle, better and more efficiently, the *non-intrusive* aspect of their operation [28]. As mobile devices become smaller and more powerful, the interaction and applications would require more space for presentation. While an alternative is to provide solutions for better use of the limited screen, increasing the size of the screen appeals to developers as well as users. Even with more effective combinations of sound and touch screens [24], the screen of a mobile device would require more space to allow more complex interaction and better presentation.

Another requirement comes from the point of view of marketing. Mobile devices, while being personal, should also be affordable and attractive. Attractiveness implies a more flexible approach in their UIs (adaptable) and an inventive approach that would generate better adoption of these devices. Even though many people have expressed the need for a mobile IA, they have most often failed to find one that satisfies their needs or attracts them sufficiently, primarily because of the weight as well as the difficulties to learn how to operate them.

3 SUMMARY

While the importance of mobility increases due to technological advances and increase in social demand, further studies should provide answers to the generic requirements for mobility. Moreover, a holistic view of what mobility means and how to develop future IAs in order to accommodate mobility are also important. Setting the requirements for a system to support mobility could be a laborious task. This is due to difficulties in forecasting and mapping cultural differences, various individual needs, social patterns and behaviour. However, some stronger threads are present and when extracted they provide the basis of the requirements for mobility, some of which have been described in this chapter. For example, while devices are required to be smaller in order to be handy and portable, display size or density should increase in order to allow more interaction and presentation. In addition, while technology advances to allow more advanced applications, social diversity requires simplicity, eventually leading to adaptation and personalisation of the mobile UI. Other requirements are remote information access, ergonomics of interaction (non-intrusive, light) and the ability to learn to operate a device in a shorter time (intuitiveness of the UI and flexibility). These requirements are mostly from the UI perspective. Other important requirements can be deduced from the information and network perspective. While more services become available and personalisation could enhance the current ones, the importance of security increases. Therefore, important requirements are the security and privacy of mobile IAs of the future.

To conclude, the list of requirements from the point of view of mobility is concerned with: display size, lightweight, ergonomics, flexibility, adaptability, network, security, personal, privacy and simplicity to learn. These have been identified as the basic requirements for a mobile IA.

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