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DESIGN OF UBIQUITOUS INFORMATION SYSTEMS FOR DIGITAL NATIVES

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Abstract

This paper focuses on how we can design Ubiquitous Information Systems (UIS) for digital natives. Digital natives are those who have grown up in a digital world, where the use of information and communications technologies is pervasive and ubiquitous, and where these technologies are used in organisational and personal contexts. Digital natives, unlike digital immigrants, like new technologies and they like change. This paper suggests that the rise of the digital native has profound implications for the design of information systems, and particularly UIS. Since many of our previous theories and models assume most users to be digital immigrants (who tend to resist new technology), a new set of design principles are needed for digital natives. We propose four key dimensions of UIS design for this new audience, namely, the system, the activity, the user, and the context that the system is designed to support. We conclude with a roadmap for the design and implementation of UIS for digital natives.

Keywords: Digital Natives, Ubiquitous Information Systems, Design Dimensions, Roadmap

1 INTRODUCTION

Digital natives are those who have grown up in a digital world, where the use of information and communications technologies is pervasive and ubiquitous, and where these technologies are used in organisational and personal contexts. These ubiquitous technologies, their networks, and associated systems have proliferated to be woven into the very fabric of our everyday life. It has become normal for people to carry mobile phones, laptop computers and personal digital assistants almost everywhere they go. It has become normal for people to use ubiquitous information systems such as Facebook, Twitter and YouTube for both personal and professional purposes. Digital natives have grown up within this digital milieu. They like trying new technologies and they like change.

Most information systems research until now has focused on the use of information systems by 'digital immigrants'. Digital immigrants are those who were not born into the digital world; they were exposed to and learnt to use information systems at some point in their adult life. An underlying assumption of much IS research is that users resist technology and they resist change. However, this assumption is based on empirical research with digital immigrants.

We suggest that the emergence of the digital native and the growth of the ubiquity of ubiquitous information systems potentially represent a fundamental shift in the paradigm for information systems research (Vodanovich et al., 2010). The purpose of this paper is to explore the design dimensions of ubiquitous information systems that cater for digital natives.

The paper is structured as follows. We first introduce ubiquitous information systems followed by a discussion of digital natives where we explore the ways in which digital natives differ from digital immigrants. This motivates us to explore dimensions of design that are particularly relevant for ubiquitous information systems that cater for digital natives. We conclude the paper with a potential roadmap for the design and implementation of ubiquitous information systems for digital natives.

2 UBIQUITOUS INFORMATION SYSTEMS

Ubiquitous information Systems (UIS) refer to systems that that exist everywhere (Sorensen et al. 2005). The term 'ubiquitous' first originated in 1988. Ubiquitous computing is defined by Mark Weiser as "an environment in which numerous computers support people's work, and the interfaces are so intuitive that people are hardly aware of the computers' existence" (Funabashi et al. 2010). This ubiquity is supported by the internet that provides digital connectivity (Srivastava 2004) to virtually any device. Weiser (1991) proposed three forms of devices that would support ubiquitous systems: tabs (e.g. iPhones, Blackberries, smart phones), pads (e.g. iPads, laptops, Kindles, touch screens), and boards (e.g. interactive blackboards/whiteboards). Poslad (2009) then extended this to include dust (embedded or untethered micro- and nano sized devices), skins (nonplanar material that can be used to cover natural and artificial objects), and clay (programmable synthetic matter). For the scope of this research, we focus on the three basic forms of devices that Weiser proposed - the ubiquitous systems we discuss would reside on any of these three forms.

As seen in Figure 1, we are currently stepping into an "Ubiquitous Society". UIS brings technologies and systems together to create this ubiquitous society that has a major impact on human life (Funabashi et al. 2008). This research therefore aims to explore UIS in the light of people (DNs), processes (activities they engage with), and networks of ubiquitous information, and communication technologies.

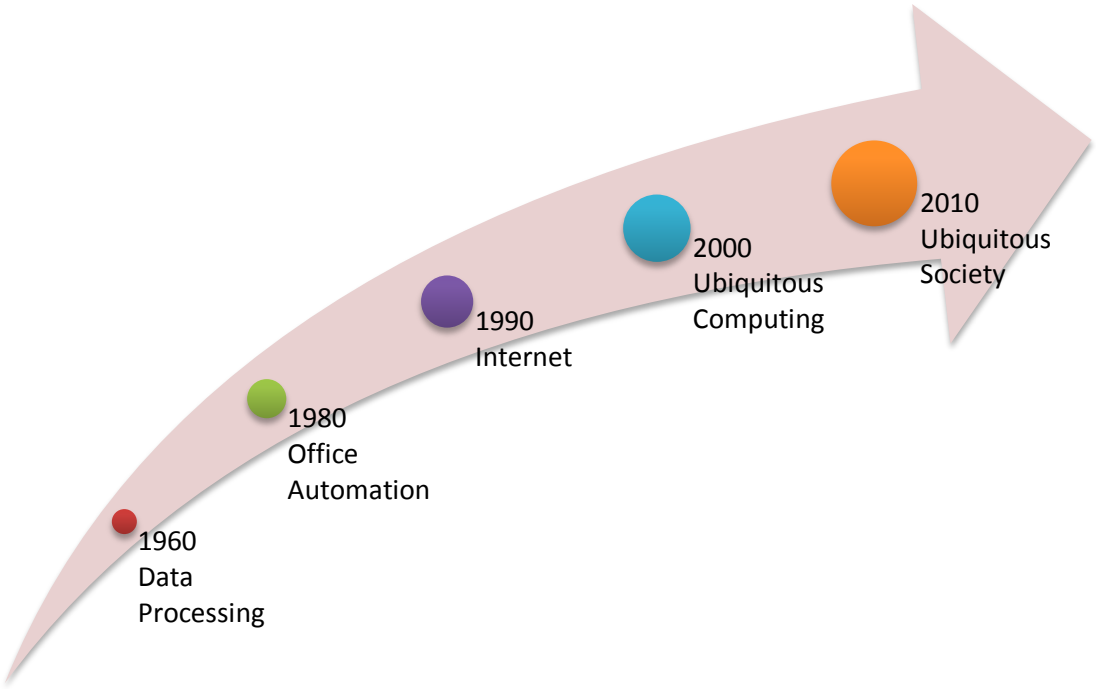

Figure 1. Evolution of Information Systems and Society (Adapted from Funabashi et al., 2008)

3 DIGITAL NATIVES

The Digital Natives (DNs) of today are the first generation to grow up surrounded by information and communications technology (Tapscott, 2008). They are "native speakers of the digital language of computers and the internet" (Prensky, 2001a). They have spent their entire lives surrounded by a wide array of digital artefacts such as music players, DVD players, mobile phones, computer games etc. This is quite the opposite of a Digital Immigrant (DI) (Prensky, 2001a, Palfrey and Gasser, 2008). However, we prefer not to make a hard and fast distinction between digital natives and immigrants: we define 'digital nativity' as something that is cultural and learnt; hence, there is a potentially continuum between digital natives and digital immigrants.

Palfrey and Gasser (2008) claim that the rise of the DNs is a result of the extensive deployment of ubiquitous technologies. This is evident by their digitally inspired methods of accessing, receiving, and processing information (Prensky, 2001b, Palfrey and Gasser, 2008). For example, "to research" for DNs is "a Google search rather than a trip to the library". DNs have not only developed appropriate skills to use digital technologies, but also use them in sophisticated ways (Palfrey and Gasser, 2008). This is because digital technologies enable DNs to multi-task, access a range of new applications, systems, and technologies, and use the Internet as a first port of call for information (Helsper and Eynon, 2010).

Most of the research on DNs is to do with DNs and education (Bennett et al., 2008, Kennedy et al., 2008, Prensky, 2005). There is also some research on DNs from a social perspective (Hayles 2007, Nisbett 2004, Small and Vorgan 2009). Last, there is research from a psychological and neurological perspective – theory that the actual wiring of the brain is different for DNs because of the way they are brought up (Prensky, 2001b). It has been suggested that there is a difference in the way a DN interacts with information (Prensky, 2001b).

While we agree that there needs to be more rigorous empirical research on the differences, for this paper we simply make the assumption that there is a difference between the two. This is based on research in the education domain (where most of the DNs have been until recently).

Table 1 below summarises the differences between DNs and DIs adapted from Zur and Zur (2010).

Digital Immigrants	**Digital Natives**
Prefer to talk on phone or in person	Prefer to connect via text, chat, Facebook, games, etc.(McMahon and Pospisil, 2005)
Text sparingly	Text more than call: 47% of teens can text with eyes closed
Prefer synchronistic communication	Prefer a-synchronistic (sequential) communication; are used to receiving information really fast (McMahon and Pospisil, 2005, Rainie, 2006, Prensky, 2001a)
Accustomed to and like manuals with clear steps	Cannot relate to manuals - They figure it out intuitively. Prefer their graphics before their text rather than the opposite (Prensky 2001a)
Assume they will work their way up the ladder in the workplace, in a linear fashion, in one career.	Try many careers, want balance among family, friends, activities, work. Prefer flexible hours, opportunity to make up work remotely, i.e., from a café on a weekend. Thrive on instant gratification and frequent rewards (Prensky 2001a)
Hang out in person, clubs, dinners, etc.	Hang out online in chats, social networking sites and games. They function best when networked (McMahon and Pospisil, 2005, Prensky, 2001a)
Value 'proper' English	Use texting and instant message shorthand: cu tomorrow; luv ya, ru going to the game?
Tell friends about a trip on the phone, or with an in-person slideshow	Tell friends about a trip by posting an album online.
Use the Internet to gather information	Use the web to socialize, play, watch videos, shows, etc. They prefer games to 'serious' work' (Prensky, 2001a, Rainie, 2006)
Think young people waste their lives online	Many aspects of life are happening only online
Think of the Internet as not "real life"	Internet is as real, and often more pleasurable, than offline life
One task or pleasure at a time	Several tasks or recreation activities at a time: Watch television, text, study (McMahon and Pospisil, 2005). They like to parallel process and multi-task (Prensky, 2001a)
Safety concerns: Physical kidnapping, assault, robbery	Safety concerns: Sexting, inappropriate pictures online, cyber stalking, identity theft, privacy invasions (hijacking of email accounts, social networking sites)
Tend to use blogging sites more as an intellectual tool to share and discuss ideas with their peers (Prensky, 2001a)	Use blogging to share personal experiences and treat personal blogging websites as forms of online journals.
Are regarded by IS scholars and practitioners as "users" of IT (and hence the extensive IS research literature on user involvement and user acceptance),	Are creators of online content (Huffaker, 2004, Rainie, 2006). Are adept at uploading their own videos to YouTube, building Web sites, communicating via txt or Twitter, and launching their own online enterprises (Sharp, 2000, Rainie, 2006).
Are resistant to new technologies (Davis, 1989)	Eagerly adopt new technologies (Vodanovich et al., 2010)
Consider devices and apps technology	Use devices and apps as natural tools the same way that some people might use a hammer or a screwdriver. Pick it up, use it, put it down. No big deal.

Table 1. Digital Immigrants versus Digital Natives (Adapted from Zur and Zur (2010)

4 DESIGN DIMENSIONS

The emergence of the digital native and the growth of ubiquitous information systems potentially pose many questions, problems, issues, and requirements for the design of UIS. Figure 2 below explores the major design dimensions of information systems, namely the system, the activity, the user, and the context that the system is designed to support. As illustrated in Figure 2, the focus of traditional IS research has predominantly been on the design of traditional organisational information systems to support digital immigrants for conducting professional/supporting organisational processes in the context of the office. IS research has largely ignored the design of ubiquitous information systems for digital natives for personal and/or professional purposes in the context of the home, office, and/or other contexts.

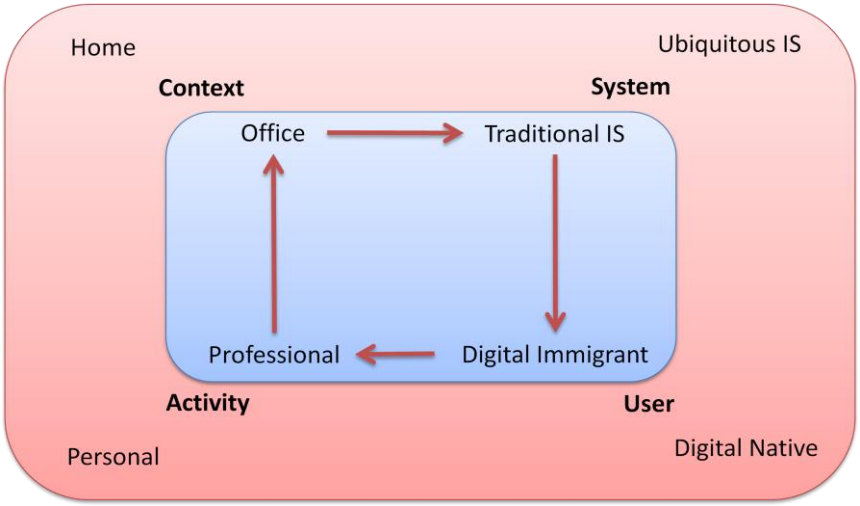

Figure 2. Dimensions of Information Systems Design (adapted from Vodanovich, Sundaram, & Myers, 2010)

Figure 2 raises many research questions on design that focus on one or more dimension(s). A candidate list of questions to illustrate the complexities are:

- How do we go about designing systems for digital natives?
- How do we design UIS for digital natives and/or immigrants?
- How do we design UIS for different devices from the traditional PC to the pad to the tab?
- How do we design a portfolio of UIS that are consistent and yet functional across devices which are of different sizes and possess different features?
- How do we design UIS for digital immigrants who are still a significant part of the workforce?
- How do we design consumption as well as creation oriented applications for UIS for digital natives and/or digital immigrants?
- How do we design personal and professional applications that allow seamless interweaving between different contexts (home, office, and other spaces) in a secure and well governed manner?

We explore these questions in the light of the four major dimensions, academic literature, and the rapid advances in ubiquitous devices and ubiquitous information systems. Each of these dimensions and the intersection of dimensions raise many sub-dimensions or issues that need to be considered in the design of the UIS for digital natives and/or immigrants for personal or professional purposes for various contexts that range from the organisational to the home. The sub-dimensions are illustrated in Figure 3.

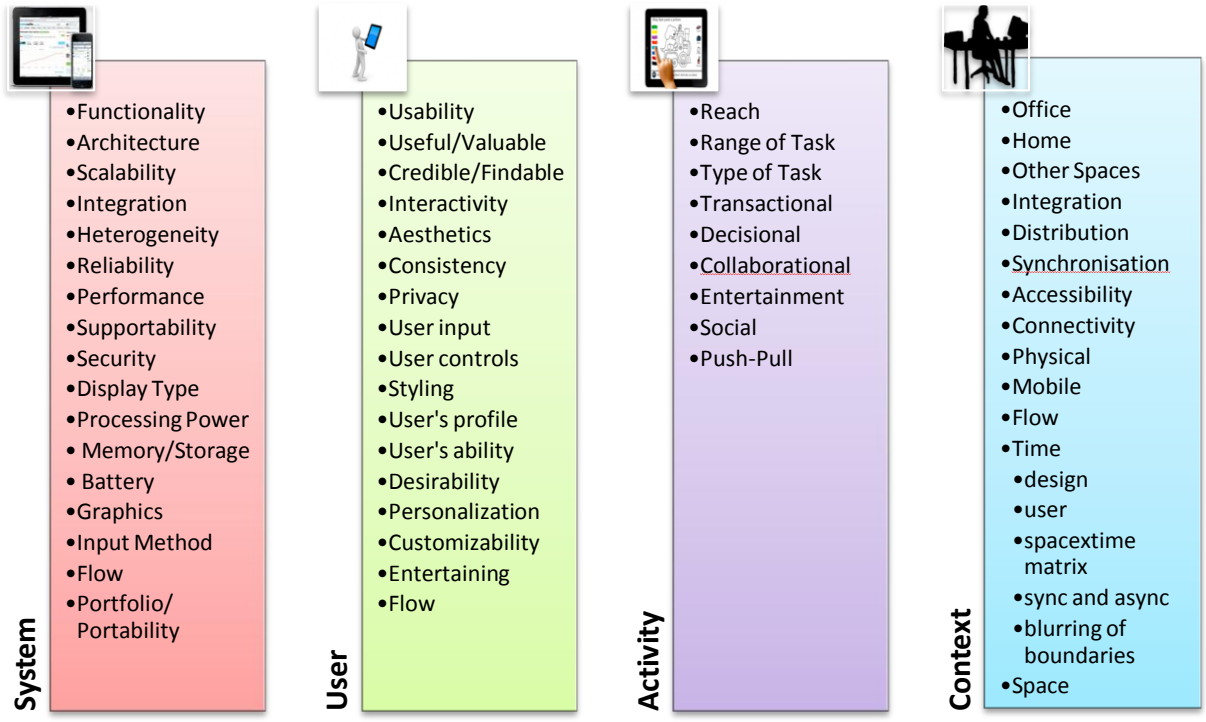

Figure 3. Dimensions and Sub dimensions of UIS design for Digital Natives

When studied holistically, the design dimensions in Figure 3 appear almost the same as design dimensions for any information system, and any type of user. However, the degree to which they are important for the DNs varies from DIs. A few dimensions are totally new.

4.1 System

Sub-dimensions: Functionality, Architecture, Integration, Heterogeneity, Reliability, Performance, Supportability, Security, Display Type, Processing Power, Memory/Storage, Battery, Graphics, Input Method

The system dimension focuses on the actual artifact being designed. In a sense, this will drive some of the other dimensions i.e. CONTEXT, USER, and ACTIVITY.

Functionality in its simplest terms comes down to serving a purpose well, or being useful. DNs use UIS extensively for multiple purposes. Examples of functions they love to see in systems are: multi-tasking and parallel processing. Popular activities done in parallel could be chatting, sharing photos, uploading videos, playing games, and responding to emails.

DNs love trying out new gadgets and technologies, and are quick to throw away the ones lacking in functionality. However, Grudin (2005) observes that switching costs can be high, and can be leveraged by extending the functionality of systems they are already familiar with. Designers should identify a system's 'core competencies' - the features that cause people to prefer that system to others. The idea is to make those functions as effective as possible, and then provide additional features incrementally. Another theory suggests that DNs are quite inquisitive. It is a good idea to make some functionality very obvious, and others embedded within the system, to be explored with time. For DNs, this makes the system more interesting to interact with.

For a technology to be truly ubiquitous, it has to be smaller and lighter is better - Apple's ipad2 released recently, a threat to the Galaxy tab because 'Apple made it too thin'. For system designers, it

means that the system should provide the same functionality be it on a desktop machine, a pad, or a tab used on the move. Some sub-characteristics of functionality are suitability, accuracy, interoperability, compliance and security (Dupuy-Chessa, 2009).

The System *Architecture* enables the translation of the logical design of an information system into a physical structure that includes *hardware (display type – tabs, pads, and boards)*, software, network support, *processing methods (*and *processing power)*, and *security*. With UIS, planning the system architecture becomes complex due to the vast possibilities of hardware, software, network support, processing methods and needs (of DNs), and with all this, a greater security threat. However, getting the architecture right is one of the most critical success factors for system design (Garlan, 2000). Sub-dimensions of the System Architecture dimension include:

- Economical and speedy, reliable deployment - using as much existing infrastructure as possible (Akyildiz et al., 2005). Ideally, we would like to have an architecture that provides *reliability* regardless of factors such as 'the power reserves at its disposal'. This calls for server based processing - thin clients and fat servers. For instance, where the primary interaction is with web server (Internet based architecture), or where the focus is on middleware since the interactions are all done remotely and need the internet.
- Scalable – DN's are very keen to try new devices in the market, and devices are likely to come and go in a volatile fashion. The number of network providers is also ever growing. A UIS architecture should be designed keeping in mind both *heterogeneity* (devices of different sizes; types; resolution, processing speed, memory, and method of input among others) and *distribution* (current and future wireless service providers (Akyildiz et al., 2005)). The architecture should enable a consistent system interface regardless of the device and network type. Factors such as data formats and media compatibility issues may also need to be considered here.
- Integration - UIS are usually an extension of a bigger, centralised legacy system. For example, a Smartphone application for ordering a pizza from Dominos would be an extension of Dominos online pizza ordering system already in place. This has implications on system *integration* i.e. maintaining the legacy system interface requirements. The question on designing a system for a portfolio of devices is raised here. Research on integration includes models used to design ubiquitous information systems, particularly, having consistent design models (Dupuy-Chessa, 2009). Other concepts such as the design structure matrix (Browning, 2001) may also be applied to designing integrated UIS for DNs. The general approaches (Hasselbring, 2000) to manage the problem dimensions of integration - autonomy, heterogeneity, and distribution can also be applied as guidelines when designing systems. A well thought system architecture, and a design that encompasses integration issues will also address the sub-dimensions *reliability* and *performance*.
- Flexible architecture – DNs like flexibility i.e. doing whatever they want to irrespective of their location. The architecture should be able to handle reconfiguration and syncing dynamically to guarantee uninterrupted *processing.* This also addresses the *supportability* and *portability* design sub-dimensions. DNs are also strongly inclined to systems that are *customisable* and can be *personalised*. The architecture should ensure that the system can be adapted, configured, and localised to provide this flexibility.
- Security - DNs today own more than one ubiquitous device, and interact with a plethora of systems over multiple networks. It becomes more important than ever to consider both current and future security threats. Primary security threats involve the method of input used for the system, and exposure to different networks. Security also has implications on the USER sub-dimension *privacy* discussed later in this paper.

An ideal architecture will need to encompass all the factors mentioned above, as well as accommodate all the other CONTEXT, USER, and ACTIVITY related dimensions discussed in this paper (See Figure 2 and Figure 3). There have been several attempts at proposing UIS architectures: from The Bayou Architecture, proposed to support mobile databases for building collaborative applications

(Demers et al., 1994) to the more recent "layered modular architecture" proposed specifically for organisations to leverage innovation (Yoo et al., 2010). The latter also takes into consideration DNs as the new workforce in organisations. Overall, the specific design processes must be coordinated so as to make the system consistent. For example, the architecture should take into consideration both the interactive part of the system, and also match it to the functionality of the system.

4.2 User

Sub-dimensions: Usability, Useful, Valuable, Credible, Findable, Interactivity, Aesthetics, Consistency, User input, User controls, Styling, User's profile, User's ability, Desirability, Personalization, Customizability, Privacy

The user experience with the system is at the heart of designing a UIS, whether it is for personal or professional purposes. Requirements elicitation and technology acceptance theories are a result of this important design dimension.

Some of the critical factors for providing a pleasant and lasting user experience are making the system *usable* and engaging or *interactive*. *Usability* characterises the capacity of the system to achieve a correct result with a given quality, efficiency, comfort, and security (Dupuy-Chessa, 2009). As discussed earlier, DNs are continually involved not only in accessing various types of information, but also creating content, and carrying out several day to day activities via these systems. Overall, for the system to be considered usable, it should use as little effort by making it easy to learn, understand, and operate (Dupuy-Chessa, 2009). Most of the usability measures can be addressed by System sub-dimensions of functionality, architecture, and integration, but it is important to explicitly consider the ergonomics of the devices on which the system will run, as well as any interference issues (Davies and Gellersen, 2002). One could argue that all users would want the system to be usable. The difference lies in their definition of what makes a system usable.

Visual interactivity is supported by dimensions such as *aesthetics*, user *controls*, *styling*, and the user's ability to *personalise* and *customise* the system. The more the user can adapt the system to their taste, the more *desirable* the system becomes. Navigation and Information design (Garrett, 2002) can be applied to enable this level of interactivity.

Privacy is considered to be one of the greatest barrier in the long term success of UIS (Hong and Landay, 2004). We believe this should take priority when addressing the user dimension. There are numerous possibilities for privacy violations. These are a result of various reasons: users not understanding and realising the digital trails they leave behind; or users not understanding the potential threats of their personal data. Davies and Gellersen (2002) believe that privacy and improved services are tradeoffs that can be resolved by empowering users to evaluate the trade-offs. As DNs create and transmit more personal information through the systems, measures should be taken in the design of the system to ensure that this information is not misused, and more importantly, that users are made aware of the potential threats of the personal information trail created.

4.3 Activity

Sub-dimensions: Reach, Range of Task, Type of Task, Transactional, Decisional, Collaborational, Push-Pull

The activity dimension looks at the variety of activities DNs engage with, using UIS, and how UIS should be designed better to support these activities.

DNs use UIS for various day to day activities ranging from personal to professional to social/community related activities. This is evident from the incredible size and variety of the Apple apps library (350,000+), the Android library (131,984), and the more recent Windows Phone 7 (WP7) library (10,000) that is growing: WP7 hit the 10,000 mark "in just over four and a half months…it took the Android Market 11 months to hit five figures, and 142 days for the iTunes app store to do the

same" (Schulman, 2011). The numbers suggest that UIS are becoming even more popular since they first started in 2007/2008.

The activities that DNs engage with can be measured based on the sophistication or complexity of the activity at hand, and the level of interaction it demands. The reach and range graph (Figure 4) can be used to illustrate this. If we place UIS on the graph, we find that most of them can be reached by "Anyone, Anywhere, Anytime", but the range is still a bit limiting. Current UIS and research on UIS is dominated by research on apps that are more consumption oriented. In terms of business activities, there is a tendency towards business intelligence/decision support and collaboration. Most UIS are therefore rich in *functionality* that supports Decisional and Collaboration tasks. However, their ability (especially on tabs and even on pads to some extent) to support enterprise oriented transactional processes is limited. We believe this is limited by both the hardware e.g. screen real estate, as well as the current system architecture design.

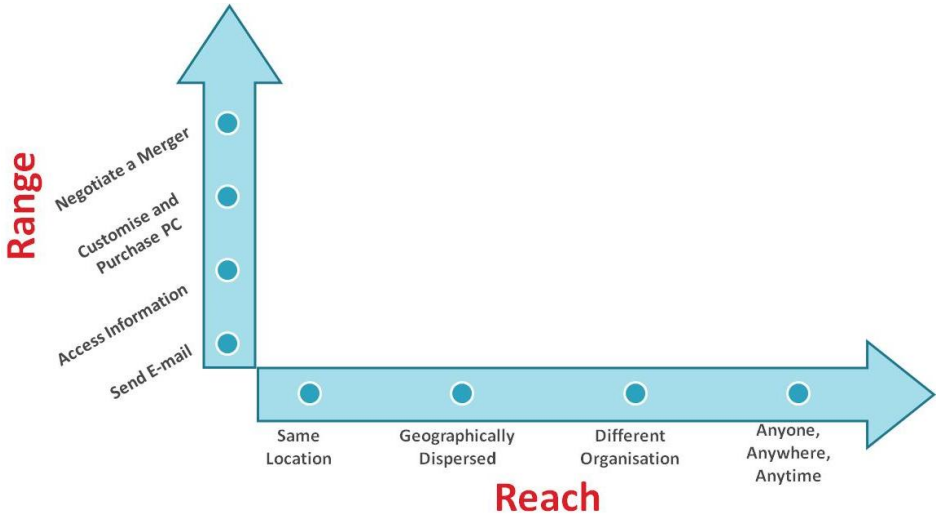

Figure 4. Reach and Range graph (Adapted from Broadbent et al., 1999)

The Push and Pull modes of information delivery for an activity is also an important element to consider when designing UIS. Current research claims that there is information overload (Toffler, 1970), and consequent issues surrounding this (lack of storage space, makes it difficult to use UIS, make decisions, etc). For a UIS running on a hardware that is generally limited in memory, it is important to take a minimalistic approach – we would ideally want a system that filters through only that information which is relevant for a given activity.

The activity that the DN engages with also dictates the type of data that the system needs to support. For example, some activities that are popular among DNs are: texting, chatting, playing games, watching videos, and taking photos. All these applications involve data. The design should therefore mull over the use(s) of the system. Ideally speaking, and looking at the current trend, DNs like to do as much as possible through UIS. With regards to the type of data, some principles applied to data-intensive websites (Ceri et al., 1999) may be relevant to the design of UIS (also driven by the internet). For example: having a conceptual schema, supporting data navigation, flexible presentation styles, personalisation, and event-based reactive processing.

4.4 Context

Sub-dimensions: Office, Home, Other Spaces, Integration, Distribution, Synchronisation, Accessibility, Connectivity, Physical, Mobile

The design of the UIS needs to incorporate a variety of contexts i.e. the system could be used in the *office*, at *home*, or in *other spaces*. This poses problems of *integration* and consistency, and poses questions about the ideal method in which the system will be *distributed* to users in the various

locations. Potential issues and downfalls for a UIS in this dimension include a lack of *synchronisation*, no *accessibility*, loss of *connectivity*, or interference in the connection. Some of these issues have been discussed under the SYSTEM dimension. However, a *functionality* that is very significant for the context dimension is "location awareness" as it enriches the way the system interacts with DNs and their environment (Ranganathan et al., 2004). As far as context is concerned, 'location-awareness' is the most critical feature in the design of UIS.

5 CONCLUSION: A ROADMAP FOR THE DESIGN OF UIS FOR DIGITAL NATIVES

In this paper we have explored various dimensions that we should consider when we design UIS for DN's. Key dimensions that were identified are the system dimension, the activity dimension, the user dimension, and finally the contextual dimension. Each of these dimensions as shown in Figure 3 have a number of sub-dimensions. While many of these sub-dimensions may seem to be similar to the design of traditional information systems for DIs, we suggest that the emphasis is different in the context of designing UIS for DN's. In fact, this poses a potential empirical question to assess the degree to which each sub-dimension is important to a DN versus a DI. While the emphasis is different there are also tensions when we design UIS for DN. For instance traditional devices such as PC's and laptops lend themselves to all types of systems from the transactional to the decisional to the collaborational encompassing creative and consumptive activities. However ubiquitous devices such as pads and tabs lend themselves more towards consumption than creation, more towards collaborational and decisional than transactional due to the limited screen real estate and data input issues. Hence when we port applications from traditional devices to ubiquitous devices there is a tension between functionality and usability. This tension is not that noticeable when we consider collaborational and decisional apps but it comes to the fore when we design transactional apps. The other notable tension is between designing for the present versus keeping in mind the needs of the future. For instance if we design keeping in mind only the digital immigrants then we could be alienating and not designing for the DN's who are entering the workforce and will be a significant part of the workforce in the near future. We suggest that designers need to keep in mind the different emphases and tensions as they go about designing UIS for DN's. In support of this we propose a roadmap (Figure 5) that considers and respects these emphases and tensions.

The roadmap is made up of a cyclic set of steps that begins with strategising, progresses to the design, implementation, and governance. The strategising step begins with attempting to understand the ubiquitous information environment in terms of stakeholders (digital natives and digital immigrants), systems (UIS and TIS), and devices (boards, pads, tabs, and hybrid). Simultaneously we need to identify the professional and personal vision and goals of the institutions, groups/departments, and/or individuals. With these steps done there should be enough information to map out the ubiquitous ecosystem. This map in turn will help us to identify end to end business and personal scenarios and processes that could take advantage of ubiquitous systems and devices and leverage the strengths of digital natives at the same time attenuating their weaknesses. This would enable us to define implementation project and its associated scope. This step leads to the next major phase namely design. In the design phase we detail the processes within the defined scope and impose and detail the UIS and DN requirements on them. This is then followed by the design of ubiquitous services catering for digital natives which is then mapped to and accessed from applications which could be on traditional platforms or in the cloud. The design phase leads onto the implementation phase which begins with the creation of an implementation roadmap followed by the transformation of (a) organisational and personal ecosystems (b) business and personal processes (c) information processes and system and finally (d) implementation of a UIS and DN governance model. Obviously the implementation phase itself need to be governed as well as the post implementation execution of processes using systems by personnel. Such governance could lead to corrections to the implementation in terms of processes, systems, and/or roles or could lead to changes in design or in some cases to the strategy. Use and governance of UIS may result in further strategising, design, implementation, use and governance in a benign cycle. We do not consider these steps nor their

sequence to be stringently followed but rather something that would be adapted to the context of the ubiquitous ecosystem.

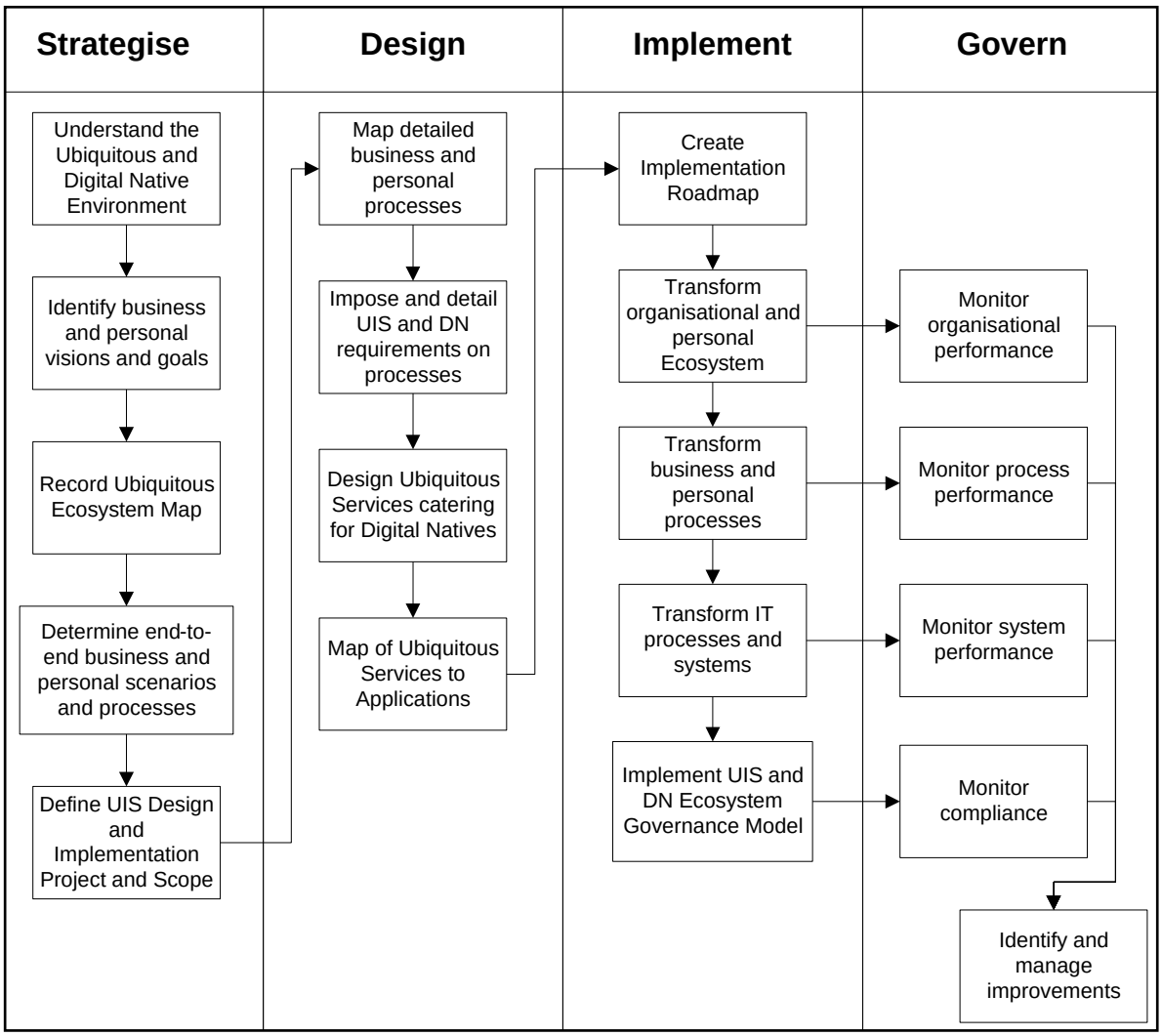

Figure 5. UIS Design and Implementation for DN Roadmap (adapted from IDS-Scheer,2006)

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