Grand Challenges in Design Research for Human-Centered Design Informatics

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Abstract. The idea of *design informatics* as a distinguished discipline is a new one, with little precedence. This paper argues for the importance of a human-centered perspective with respect to the emergence of this newly nascent field of design informatics—a perspective which may be termed *Human-Centered Design Informatics* (HCDI). The paper proposes four grand challenges that are essential to the foundations of HCDI, specifically (i) understanding the *living nature* of information, (ii) understanding the relationships between interaction design and information, (iii) understanding how to design for sustainable and engaging social interactions mediated by information technologies, and (iv) understanding the multi-cultural and globalization issues implied by the use of the materials of information technologies in design.

Keywords: design informatics, information and communications technology (ICT), human-centered design, design education, design research, human-computer interaction (HCI).

1 Introduction

It can be said without controversy that we face grand challenges in every aspect of design research and practice in HCI as new information and communication technologies emerge. The explosion of information and communications technologies (ICTs) that are now available to people everywhere has implications for changing the way we think about design. The more that information becomes intrinsic to our daily lives, the more important it is to establish the field of *design informatics*. In this paper, we propose four grand challenges that can be the initial attempt to be addressed as design research agenda in order to achieve the foundation for *human-centered design informatics*. We promote the term, *design informatics*, in this paper, instead of human-computer interaction, in order to encompass larger perspectives of the relationships between design and the materials of information technologies in all contexts and not just the interactive ones.

The term, *design informatics*, has lately started to gain some attention from both design disciplines and information science disciplines. Some examples include the approach by Harvard Design School, the Center for Design Informatics (CDI) [18] where *design informatics* was defined as "research on the impact of information technology and the Internet on the real estate, design and construction industry, on

multi-media and visualization, and on Internet-based learning," which is from a design discipline perspective, and the approach by David Hendry in University of Washington, Information School, who views *design informatics* as a study area that enables "a deeper understanding for design that can be obtained by taking an information perspective on design activities," [9] which is more from an information science perspective.

We appreciate both directions on defining *design informatics*, but in this paper, we like to define it in a way that may cover both perspectives. We define *design informatics* as having two important dimensions, namely (i) the application of information technologies to design as an agency in the world, and (ii) design using the materials of information technologies, through the emphases on design values, design actions, and design reasoning. We view it as a field of study of what the digital information age enabled people to do, behave, and live with new information technologies, and how various insights induced by such research can inform the design of new ICTs. This perspective resonates with various researcher perspectives including "Information Ecologies" by Nardi and O'Day [15], "Smart Mobs" by Rheingold [19], and "Infotopia" by Sunstein [23].

In this proposal of a definition of *design informatics*, we are particularly interested in establishing a human-centered perspective of design informatics. Many ICT examples, which are not anymore only about the interactions between a person and a computer, have led us to focus on *people-to-people interactions* mediated by computing-enabled tools and *experiences* emerging from interactions with such tools. Starting from human activities and their experiences becomes inevitable. In this regard, we like to propose that *design informatics* itself should imply the importance of the human-centered perspective.

Examining what emerges from the relationships between people and technologies and how technologies take place in our daily activities made us realize that supporting the design of the emerging forms of technologies to address those two foci becomes even more difficult than ever. In earlier days, there was an obvious setup of the interactions between human and computer when the forms of computers were rather homogeneous. In those days, computers were also more for "non-discretionary" use rather than activities people can choose for what to do with computers [8]. It was far easier to predict what people would do to interact with computers back then. It was far easier to formalize design processes and to measure the effects of design outcomes. However, with these two emerging foci now, it is impossible to think about design in such ways. In this regard, these two foci motivated us to deeply think about what the significant challenges we face in establishing human-centered design informatics which will be able to address those two foci.

In this paper, we particularly propose the challenges which we face especially when we think about the *design research perspective* when developing new ICTs rather than computer science and engineering or information science oriented research perspectives. By design research perspective, we mean the study to improve design knowledge and activities for designing systems. What needs to be addressed is how to advance design knowledge to create better systems which will benefit to human well-being and society welfare.

We propose four grand challenges as an initial proposal when we target to establish the field of *human-centered design informatics*. They include 1) understanding the

living nature of information behaviors that emerge from its abundance and pervasiveness—e.g. "ambient findability" [14] and "everyware" [7]—through the understanding of the nature of digital materials which are what enable the abundance and pervasiveness of information, 2) understanding the relationships between interaction design and the living nature of information, 3) understanding how to design for more sustainable and more engaging social interactions, and 4) understanding multi-cultural and global issues.

In what follows, we will discuss in detail why each challenge is important, as well as its definition, examples that show the importance of the challenge for human-centered design informatics, and keys to be considered in design research to address the challenge.

2   The First Challenge: Understanding the Living Nature of Information

We believe that the first challenge is to understand *the living nature of information that emerge from its abundance and pervasiveness* caused by the advent of new technologies—this nature may be construed as a complex system of *living* information. Nardi and O'Day introduced the term, "information ecology", to describe and emphasize the nature of the system that involves "people, practices, values, and technologies" as a coevolving collection [15]. They viewed that the system of this collection behaves like a biological ecology system. Every part of the information ecology adapts to its own ecology to be able to survive and optimize itself to dynamically changing conditions. The ecology is evolving, has its own history, has interconnections among the components within it, and is never static [15].

The most interesting here for us to think about is why in this system the technologies which connect people with information and with other people become also an active part of the ecology rather than fixed tools that can be fully controlled by people and their practices. We believe that this is possible due to the power of digital technologies which created the *living nature of information*. Instant creation and publishing of information, unbounded and unconfined sharing of information, and access to information without physical bounds are what become possible due to the digital technologies and what made information behave like living creatures which actively take a part in an *ecology*.

We have observed this nature of information from various existing examples. Some examples of big successes to be self-sustainable and pervasively used web applications especially in US include youtube.com [27] and wikipedia.org [26]. Anonymity, instant responses, ratings, and tags are all important features that enabled such success. With information technologies, people smartly utilize and exploit what is available to them to be able to achieve their needs and desires. It is not anymore for people to use them only to achieve certain predefined tasks. What we now face is the uncontrollable expansion and use of information available to almost everyone. The Time Magazine assigned the Person of the Year for 2006 as "You" [22]. The Managing Editor of the Time Magazine, Richard Stengel says, "you, not we, are transforming the information age" (p.8) [22].

We believe that this nature of information must be carefully understood for better design of ICTs. And it is a grand challenge because it is impossible to see the whole *ecology* in a clear picture, and impossible to predict what will happen in the whole system.

When we face this challenge, we must make sure that design should not try to figure out a fixed structure of information to visualize or to provide interface to access to the information without accommodating the *living nature of information*. The design case of iPod, shows a good evidence of the tight relationship between the properties of the data and the ways to interact with them. The reason for coming up with the wheel interface was to manipulate more than 200 or 300 songs far more smoothly than pushing a plus button "a thousand times" which was popularly used in regular mp3 players at that time [12].

We must also understand the nature of *digital material* which is the cause of the living nature of information. The term, *digital material*, is carefully examined in this sense by Löwgren and Stolterman [13]. In the process of digitizing information we are creating vast amounts of digital material. Digital material has unusual properties that are the reason for the success of modern information technology. Digital material makes common material properties like reproducibility, storage, and transportation mean new things. At the same time, common economic principles such as the relation between abundance/scarceness and prize are radically challenged. Designers are traditionally professionals who deeply understand and manipulate the natures of materials they need to deal with for ultimate designs. When designers create information technology applications, it is critical to understand what digital technologies—basically *digital material*—have enabled in this current world as well as what will be enabled in future. Understanding digital material is not about studying engineering or science of digital material, but more about studying the consequences that may influence user experiences and society due to their nature.

This definitely has implications for the methods designers use when designing ICT products, the discourse that defines design philosophy, and the notion of design research and education.

3   The Second Challenge: Understanding the Relationships Between Interaction Design and Information

We believe that the second challenge is to understand *the close relationships between interaction design and the living nature of information*. No one has specifically emphasized or identified that the living nature of information is what matters for how we design interactions of ICT products. This is a challenge since, first, without understanding the living nature of information, which is the first challenge we identified in the previous section, it is impossible to identify the relationships between the two, and second, it is a space people have not much explored as a design consideration yet although people have been unconsciously addressing it. The example of iPod's wheel interface design described in [12] clearly shows us the importance of this issue as we mentioned in the previous section. The nature of information and data, which the device provides the access to, was what drove the design of its interface and interaction technique. And various innovative ways of visualizing and manipulating information

have been created, and there is also a blog, namely, "Information Aesthetics" [5] where the collection of such new approaches has shared. The core idea here is the living nature of information created new ways of visualizing and interacting with information, and it is not anymore confined to few ways of controlling or interacting with it. What becomes important here is the quality of experiencing the information.

We propose that it is important to clearly conceptualize this space as an important design consideration within which we can closely identify how interaction techniques should be designed to support the access, sharing, and manipulation of different types of information used for different purposes. People have much more focused on new features, new interaction techniques, and new forms of devices without a close examination of how the types of information, the amount of data, and the purpose of the use of information, and the nature of the content in relation to the context of its use and manipulation are related to the design and creation of such new interaction techniques. Although the information visualization area has been thriving, people in this area have not closely examined in relation to the interaction techniques to manipulate such information, or vice versa. Those two areas were rather separately researched rather than seeing the relationships. We here claim that understanding the relationships between these two areas is what we need for better and successful design of ICT products.

One way to address the issue of understanding these relationships is to consider the differences and similarities between *digital* and *analog* qualities of experiences. When we look at these relationships, it is not just about the creation of new forms of devices or about real (physical) and virtual representations. It becomes more about how people perceive and experience the information through the mediated interaction techniques to manipulate various types of information, which can be categorized as *digital experiences* and *analog experiences* although all the technologies are digital.

Digital experiences are commonly described by such terms as *replicable*, *precise*, *artificial*, *discrete*, *scientific*, *objective*, *clean*, *modern*, *cold*, and *hard*. **Analog** experiences are commonly described by such terms as *imprecise*, *continuous*, *proximate*, *warm*, *emotional*, *sensual*, *natural*, *soft*, *rough*, *retro*, and *humane*. Ironically, the abundance and collaborative creation of information through digital technologies justifies a metaphor of *living information* to denote the dynamic, organic behavior of information in the modern milieu—which means that digital information itself behaves like *analog* information. As a consequence, the manipulation of digital information becomes more of an analog experience as well. For example, browsing huge amounts of information is no longer an issue of precision. It is an issue of discovery, proximity, and exploration. New ways of visualizing information also mirror the analog aspects of human experiences as well. Since humans live in an analog world, it is natural for them to interpret digital information in terms of the qualities of analog experience. Thus, designers need to account for how digital material will be interpreted in terms of analog experiences.

Many examples in "ambient intelligence" [24] show how the analog quality of experience of perceiving information can be designed through digital technologies. For example, Ambient Orb [2] can visualize various types of information such as weather, stock market, and horoscopes with a glowing color light spectrum (Figure 1(a)). The Orb does not tell you precisely any textual information, but it proximately describes the level of information so that people can quickly capture the information they need.

This is a very analog quality since it is continuous, proximate, and imprecise. Due to these qualities, the way people experience this information is very different from the way people experience when they directly log into websites which precisely show such types of information with rich texts that is more of a digital quality of experience.

Another example includes Attenex Patterns [3] which is a product for information discovery and search. Attenex Patterns (Figure 1(b)) is a tool that discovers useful patterns and facts from information-rich documents "to rapidly identify relevant content for litigation, investigations and regulatory response projects" [3]. In order to enable this, it provides unique ways of exploring information with analog-like interfaces. The query interface allows a user to put a chunk of texts in a search box, which are related to or precisely same with what they like to find among a ton of documents in their database. Then a slide-bar in the query interface that is analogous to an analog quality enables the user to adjust different thresholds for defining the level of relatedness to the queried texts among different documents in the database.
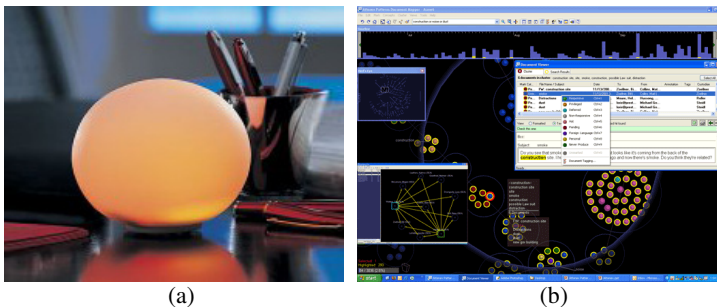

(a)   (b)

Fig. 1. (a) Ambient Orb (the source of picture: http://www.ambientdevices.com); (b) Attenex Patterns (the source of picture: http://www.attenex.com/products/documentMapper/visual/)

Earlier fears about information overload proved to be unfounded and people turn out to be comfortable with this abundance of information. Information was always a part of the human environment, even before the digital age. And now with digital technology, it supports new ways of creating, sharing, and using information that contrast old ways. These new ways have changed our interactions with information and our understanding of the very nature of information. Our interactions with information have become abundant, pervasive, and ubiquitous. With the advent of mobile devices, especially those that are internet connected, we have pervasive access to information that augments our natural memory. Such extensions of ourselves imply the need for new ways of thinking about the design of products which embed the materials of information and communications technologies.

With these technologies, we now not only have a pervasive access to information but also an ability to create new information anytime anywhere by anyone. In this regard, we not only think about how the *access* to different information types drives the ways of thinking about interaction design, which was the primary discussion above, but also we must think about how the interaction design to support the *creation* of information affects the ways of information behaviors and its *ecology*. An example for this would be the case of the success of SecondLife.com where attracted almost

3.5 million people [20]. The fact that it allows people to be able to create their own spaces and objects in their virtual world is what makes it different from other virtual online social spaces which may be less popular than Second Life, due to the fact that people are confined by what is given, and do not have much freedom to expose their creativity in such spaces unlike Second Life.

4   The Third Challenge: Understanding How to Design for Social Interactions

We believe that the third challenge is to understand *how to design for social interactions* mediated by ICTs that support the social nature of human activities. The form of interactions with information on the web has significantly changed over time. A new term denoting the new trend in web culture—Web 2.0 [16]—has transformed web culture from static, information advertising, and one-way communication to dynamic, social-centered business models, and multiple-way communications.
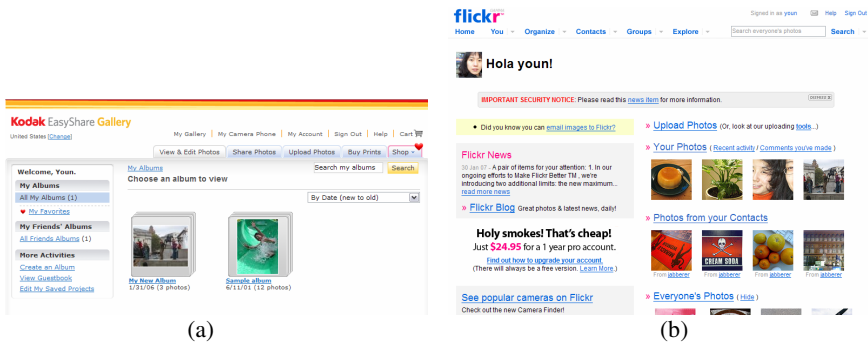

Fig. 2. (a) Kodak EasyShare Gallery (www.kodakgallery.com); (b) Flickr (www.flickr.com)

In order to explore how the design of digital information media influences the social nature of people, we compared two websites, one representing the characteristics of the first generation of web sites, Kodak EasyShare Gallery [11], and the other one representing the characteristics of the new generation of web sites, Flickr [25] (Figure 2 (a) & (b)). Kodak EasyShare Gallery which originally called Ofoto was launched in 1999, and Flickr was launched in 2004. Although Flickr started far later than Kodak EasyShare Gallery, Flickr was ranked as the 41st place of the most popular websites in Alexa.com on February 11, 2007 [1], and Kodak EasyShare Gallery was not even in the list for the top 500 sites. Although it may still be arguable if the number of page-viewers and the number of visits, which are the major units to determine the most popular websites by Alexa.com, are more important measurements to evaluate the level of support for the social activities than the market share of visits—according to [17], Kodak EasyShare Gallery had a slightly higher market share of visits than Flickr on June 21, 2006—we think that the number of page-views and visits to the site are better measurements to understand how actively the site users are

involved in the community for the sharing of photos. Our comparison of the designs of these two sites is described in Table 1.

Table 1. Comparing the designs between Kodak EasyShare Gallery and Flickr

Compared Aspects of Design	Kodak EasyShare Gallery	Flickr
Used terms	• Album-oriented—individual photos are hidden under albums (e.g. my new album, sample album) • Relationship-oriented (e.g. friends)	• Photo-oriented—individual photos are visible at the first place (e.g. your photos, photos from your contacts, everyone's photos) • Undefined relationships (e.g. contacts, groups)
Link organization	• Sharing photos is 5 steps deep • Commenting on photos is 5 steps deep • Viewing the comments is 3 steps deep	• Sharing photos is 2 steps deep • Commenting on photos is 2 steps deep • Viewing the comments is 1 step deep
Photo browsing and organization	• Album oriented • Comments are hidden • Updates in friends' albums are not visible	• Individual photo oriented • Comments are visible • Updates in contacts' photos are visible

Through this analysis, we realized that what need to be considered for the design of social interactions are as follows:

- how it will allow sharing information,
- what terminology it will use for links and interface elements,
- how it will create a sense of community, and;
- how the focal point of the application and its interface design will be oriented to social features.

These four considerations above are not the ones which can easily be addressed in design without any additional social research support. To be able to accommodate these considerations successfully, we must understand the nature of social context, social desires, and the nature of bonding experiences. This will require even more active research collaborations between social sciences, social informatics, and design informatics.

5   The Fourth Challenge: Multi-cultural and Global Issues

We believe that the fourth challenge is to understand *multi-cultural and global issues* even with the introduction of identical technologies in the different parts of the world, such as information sharing issues caused by language differences or cultural characteristics. In addition, an even more important thing is to understand the fact that not every country or culture has same ways to interact with information. For example,

wikipedia.org [26] is not much popular in South Korea comparing to US or other countries which have highly populated Internet users, although South Korea is one of the top countries with the highest internet penetrations [10]. The interesting thing is that the countries like Portugal and Netherlands are shown as places where the number of articles in the Wikipedia is very high [26] and they are not even listed as the top 20 countries of internet users in [10]. Such data imply that the ways people use and create information through digital technologies are different according to cultures, lifestyles, values, and countries.

To be able to understand what causes such patterns, it is important to be able to elicit tacit cultural assumptions and patterns. There are several established methods for this such as ethnomethodology-based methods with which researchers can reveal implicit patterns through defamiliarization [4], using technologies as probes to understand "how people perceive and work with technology" [21], and the cultural probes technique with which we use commonly known artifacts as probes to trigger "inspirational" and tacit responses from the targeted participants whose culture is unknown to designers [6].

We need more of research and development for such methods and techniques, and the research on cultural characteristics in relation to the use of information technologies should be much more published and shared within the HCI and design informatics field.

6   Conclusion

In order to address these four challenges in the design education and the design field, we should develop systematic education and research programs that help designers establish *interdisciplinary, culturally and socially sensitive, and integrated mindsets*. Educating designers who can communicate and work with people in other fields is one essential part of the equation that needs to be established for human-centered design informatics. The issue of creating a culturally and socially sensitive mindset is particularly important when we think about the third and the fourth challenges, although the first two challenges are indirectly related as well. All these discussions lead to the discussion of establishing the new direction of design research—*human-centered design informatics*. We will further discuss what design research activities need to be addressed and implemented in our field as future agenda in the full paper.

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