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The Role of Information Architecture in Context-Aware Adaptive Systems

Abstract

Information architecture, concerned with the structural design of information spaces/systems, and context-aware adaptive systems, supporting situated system use through a computational approach, are presented as two converging fields. Specific points of convergence include balancing immediate use with awareness, tackling choice overload and promoting discovery, and dealing with the increasing complexity of user context. The role of information architecture can be to apply a holistic view of systems, users, and context, thereby promoting awareness and discovery over of specific task efficiency measures. Further, designing meaningful structures from large, complex sets of information, is an information architecture skill well-suited for addressing the issues of context.

Introduction

Several research fields are concerned with creating software that somehow is beneficial for people to use. Recognizing that user needs and capabilities vary by situation, research into context-aware adaptive systems tries to better supports these variations. However, much emphasis is put on the effectiveness and efficiency of specific tasks, and not as much on longer-term support for awareness and discovery. Furthermore, the complexity of user context is increasing to include not only physical context, but a pervasive digital, social context as well.

These factors combine to introduce and emphasize certain software design challenges. This paper presents three of these challenges as points of convergence between the fields of context-aware adaptive systems, and information architecture. After a presentation of the design challenges, an overview of the computational approaches within context-aware adaptive systems is given, followed by a discussion of the role of information architecture.

The aim of this elaboration is to highlight a research area where information

architects typically are not involved, but which seemingly has clear connections to the field. Making such connections visible may afford new design perspectives, and can perhaps encourage interdisciplinary cooperation.

Three Software Design Challenges

Balancing Immediate Use with Awareness

Nowadays, people expect to be able to use a new product right away. This prompts immediate use, without consultation of manuals or built-in documentation. Software designers, in turn, anticipate this behavior, and design interfaces which support the instant-use, satisficing behavior that is prevalent. This is often achieved by employing design principles such as minimalism, where only the most important functionality and content is displayed.

Simplifying an interface, to help guide users through a system, is in conflict with another possible goal: to provide an overview of the available functionality and content. Awareness of possible system uses is an important issue, particularly as we see a transition from desktop computers to mobile, non-PC devices. When moving away from traditional user interface metaphors, people may not be able to rely on past experiences to help guide the use of new systems.

The smartphone specifically, is becoming a primary way of interacting with digital services. This is in spite of some inherent limits of a small-screen device, placing further constraints on user interface design. There is a tension between task/information amount and complexity on one hand, and interface constraints on the other.

People prioritizing immediate use of a system rather than taking the time to optimize their use, it is not a new phenomenon. This was called the Active User Paradox, by Carroll and Rosson (1987). They observed that once computer terminal users were active, the initial usage strategies were kept, in spite of more efficient strategies, which would save time in the long run, being available. As they put it, "(computer users') skill tends to asymptote at relative mediocrity."

Carroll and Rosson described the background for the active user paradox as two mutually reinforcing conflicts, one motivational and one cognitive. People were seen as motivated by the need to perform concrete tasks, with

a paramount goal of throughput. They received immediate reinforcement from their work, in a way not provided by learning about the system. On the cognitive level, Carroll and Rosson referred to the well-known assimilation bias, where "people apply what they already know to interpret new situations".

These conflicts can be handled in different ways, and Carroll and Rosson discussed ways to attack, mitigate, and design for them. A general theme in their discussion was towards the minimalist and simplifying approach that now is common. This may be seen as a paradox in and of itself, where the efficacy of a subset of tasks is greatly enhanced at the expense of others (where some may never come to the user's attention).

Choice Overload and Discovery

With the rapid growth of native and web applications for mobile platforms, we may soon find ourselves in a time where every shop, organization, and landmark provides some form of mobile service. This constitutes a challenge for any user, novice and expert alike. How are users supposed to know which options are available, and which options that are relevant to their current and long-term needs?

Mobile platform vendors and third-party companies are aware of this challenge. Apple, for instance, provides application recommendations through its Genius service, based on applications you and others have downloaded. There are also many curated lists of applications, and even some services which compile recommendations from users' contacts. However, a user's need may vary greatly according to the particular situation.

Further, users may not be able to adequately express their needs within the bounds of a system (if the need even is known). How would a more personalized approach work? Which personal data can be further used to characterize a user's information need and goals?

Norman (2002) emphasizes that actions may not be planned, but opportunistic. "For many everyday tasks, goals and intentions are not well specified: they are opportunistic rather than planned. Opportunistic actions are those in which the behavior takes advantage of the circumstances." This aligns with Taylor's 167 distinction of a conscious information need, separate from a visceral one.

These are further distinguished by Taylor from the formal need (what can be expressed), and the compromised need (what can be expressed within the bounds of a system). This prompts another challenge, or opportunity, for

users: What new things can be pursued, based on what is available? That is, which needs or goals, that are not yet conscious, can be made known? These are complex issues, involving user goals, information behavior, contextual factors, as well as properties of information.

The Complexity of Context

Information is becoming pervasive, as expressed by Resmini and Rosati (2011):

> *(m)obile devices, networked resources, and real-time information systems are making our interactions with information constant and ubiquitous.*

We have ubiquitous access to information, but systems also have increasing access to information about us. Permanently connected mobile devices are very common, and are often equipped several sensors such as GPS, accelerometer, gyroscope, light sensor, microphone, etc. Being networked, these devices can also access distributed sensors, e.g. in smart home scenarios (Davidoff et al 2006). In the same markets, the use of social networking is prevalent, and increasing, enabling more and more people continuous access to information about friends and other contacts. All of these factors can influence the use and design of systems and services.

Having access to continuous streams of possibly relevant information, may enable more opportunistic actions, but only if this information is made visible. What is considered relevant may change with the user's situation. Being at home with some free time ahead will probably yield a greater openness to new input, than being at work with several tasks due later that day. Given access to location and task/calendar data, a system could adjust what information is presented.

In spite of similar examples being easily imaginable, such situational awareness is not easy to achieve. In fact, it seems to be quite the opposite – the amount of possible interpretations of a given situation are numerous. One framing of this problem is each person simultaneously has physical, digital, social, and cognitive contexts, all affecting, and being affected by, their interaction with digital systems and services.

Computational Approaches: Context-Aware Adaptive Systems

A system can alter its state or behavior to adapt to changes in the

environment, or in users themselves. Personalization can be used as a catch-all term for this, describing systems that somehow tailor themselves based upon "a model of the behavior, needs, or preferences of (an) individual" (Morville & Rosenfeld 2006). In research, personalization has been studied from many perspectives, with varying goals, under different names.

Context-Awareness. "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task" (Dey 2001). Context in this sense is "any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" (Dey 2001).

Adaptive Systems. Adaptive systems "are systems which can alter aspects of their structure, functionality or interface in order to accommodate the differing needs of individuals or groups of users and the changing needs of users over time" (Benyon & Murray 1993).

Adaptive Interfaces. Adaptive interfaces "autonomously adapt (their) displays and available actions to current goals and abilities of the user by monitoring user status, the system task and the current situation" (Rothrock et al 2002).

Intelligent User Interfaces. Intelligent user interfaces "are human-machine interfaces that aim to improve the efficiency, effectiveness, and naturalness of human-machine interaction by representing, reasoning, and acting on models of the user, domain, task, discourse, and media" (Maybury 1998).

It is apparent that these categories have considerable overlap, though research tends to be self-classified as either context-aware, adaptive, or intelligent. Sometimes however, a combination of terms are used, e.g. "context-aware adaptive applications" (Sama et al 2010). Shneiderman's work on multi-layer interface design (e.g. 2003) is also relevant, though not further considered here.

In this paper, "context-aware adaptive systems" is used, and refers to the union of the above categories. Put simply, these are systems which utilize data related to the user (that is, context), with the purpose of performing an adaption considered beneficial according to some metric. Key issues then, include defining context scope and possible states within that scope, determining signals to be used for context acquisition, deciding what adaptations are suitable, and defining metrics for evaluating system performance.

Context Signals and Scope

Context-awareness was originally described by Schilit as being able to "promote and mediate people's interactions with devices, computers, and other people, and it can help navigate unfamiliar places" (Schilit et al 1994). Today, it seems appropriate to include both digital and physical spaces within the notion of unfamiliar places.

As possible context scope increases, so does the need for designers of context-aware adaptive systems to carefully define what aspects are relevant to their specific problem. In line with this are the inherent benefits of having a clear set of discretely defined variables (signals) to consider. Computational approaches, employing machine learning and classification techniques, are made easier by such limitations. Location, being very clearly defined, has been one of the most used types of context, e.g. 13 of 14 systems reviewed by Dey and Abowd (1999).

While it clearly can be useful to limit context scope to a few factors, it is also interesting to consider what a very rich understanding of a user's context might entail. A successful project in that direction is the context-aware development environment developed by Kersten (2007), enhancing long-term navigation efficiency of programmers. Kersten's model of task context uses analysis of interaction history with a programming project. It shows the importance of domain experts in designing successful context-aware adaptive systems.

Goals and Performance Metrics

One focus of context-aware adaptive systems is improving some aspect of a user's interaction while performing certain tasks (in an application of a specific kind). Measures like efficiency is then important, e.g. amount of time doing primary work versus navigating (Kersten 2007).

One of the goals of adaptive interfaces is to present the user interface functionality in such a way as to increase task efficiency, which can be measured using task completion times and error rates (Findlater & Gajos 2009).

By focusing on efficiency, issues such as discovery and awareness may be neglected. This negative correlation has been confirmed in experimental studies by Findlater and McGrenere (2008, 2010). Also in some contrast to efficiency measures, is evaluation from a user experience and user satisfaction perspective. User-centered evaluation is not unheard of, and one review

found that usability, perceived usefulness and appropriateness of adaptation commonly are assessed (Velse et al 2008). The same paper notes however, that some of these evaluations are of low quality, possibly due to the fact that

> *most evaluators of personalized systems are computer scientists and not specialized in evaluation.*

Höök's observation from 2000 still applies:

> *Most intelligent user interfaces, such as e.g. user agents, are designed with the aim of being of use in the long run – not only during a short, controlled, user study. Proper evaluations of whether the system supports users' real tasks must include an analysis of the organisational setting, users' activities and cooperation with each other, usage of other tools, etc.*

The Role of Information Architecture

Information architecture is about organizing and simplifying information, designing, integrating and aggregating information spaces/systems; creating ways for people to find, understand, exchange and manage information; and, therefore, stay on top of information and make the right decisions (Ding & Lin 2009) [1].

Morville and Rosenfeld (2006) stipulated that good information architecture is informed by users, content and context. While they concede that the basic model is an oversimplification, they specifically note how the concepts are intertwined "within a complex, adaptive information ecology." They also stress the "dynamic, organic nature to both the information systems and the broader environments in which they exists," continuing, "we're talking complex, adaptive systems with emergent qualities."

These statements point to a very clear connection between information architecture and context-aware adaptive systems, as described above. Yet, these are not fields with much interaction.

More recently, in the foreword to Pervasive Information Architecture (Resmini & Rosati 2011), Morville further describes how "the world and the Web intertwingle." He asks, "How do we rise to the new challenges of creating paths and places that bridge physical, digital, and cognitive spaces?" From this point of view, information architects are (in part) responsible for creating these paths. This begs the question of how similar paths or spaces can be for different users, existing in a multitude of contexts.

Dealing with Context

When Morville and Rosenfeld (2006) wrote about context, they did so from a business and organizational perspective, exemplifying with "business goals, funding, politics, culture, technology, resources, and constraints". While these indeed are valuable things to consider in a design and development team, they do not constitute user context. It is interesting to consider how information architecture may be viewed, from the alternate viewpoint of context representing each personal situation.

Wurman defined an information architect, in part as "the individual who organizes the patterns inherent in data, making the complex clear," and "a person who creates the structure or map of information which allows others to find their personal paths to knowledge" (Wurman 1997). A challenge when dealing with context-aware adaptive systems, is that patterns of data are even less inherent than in static systems. Which patterns are meaningful depend on the user's current context. This makes the second part of Wurman's definition more important – every context already exists, what is missing is a structure or framework describing meaningful contextual components, and the relationships of these components [2].

The pervasiveness of user context is both an interesting and complex design challenge. While many aspects of context may be generally applicable, each system or service has to consider which signals are of special importance to supported use cases. From a practical point of view, determining the most important signals is needed to facilitate actual implementation. Information architecture is positioned to approach context-aware adaptive systems holistically, adopting a human-centered perspective of context.

Promoting Awareness and Discovery

Applying information architecture design to context-aware adaptive systems may also provide an opportunity to focus more on awareness and discovery. Thinking in terms of understanding, managing and staying on top of information, while including knowledge on human information behavior, are all things that may currently be lacking.

Research within context-aware adaptive systems may sometimes be forced to focus on very specific problems, in order to achieve measurable, quantifiable results (e.g. adaptive menus (Park & Han 2011)). Information architecture may help narrow the design space in everyday information use. Indeed, Höök (2000) described four key issues for bootstrapping the adaptive system: identifying hard problems, finding user characteristics related to the hard

problems, finding ways of inferring characteristics from interaction, and finding appropriate adaptations.

Information architecture may be suitable for tackling all of these issues, including information as well as user characteristics.

Informing Information Architecture

New types of systems, with context-aware and adaptive properties, are being enabled by computation. These systems represent a design approached focused on creating underlaying rules, rather one specific final result. Being exposed to methodologies, ways of thinking, and results within disciplines as computer science, may help information architects envision new designs [3].

Conclusions

As the scope of information architecture widens to include pervasive and ubiquitous comping, points of convergence with other fields are becoming clear. One such field is context-aware adaptive systems, which applies a computational approach to supporting situated systems use. This paper has presented some design areas where this convergence is most apparent, including balancing immediate use with awareness, tackling choice overload and promoting discovery, and dealing with the complexity of context.

> *(We) live in a world where relationships with people, places, objects, and companies are shaped by semantics and not (mostly, or only) by physical proximity; where our digital identities become persistent even when we are not sitting at a desk and in front of a computer screen, then we are reshaping reality. Conversely, we need to reshape information architecture to better serve us and our changing needs. A huge challenge indeed, but where there is a challenge there is an opportunity. (Resmini & Rosati 2011)*

Information architecture can be reframed as an enabling layer in context-aware adaptive systems. Designing meaningful structures from large, complex sets of information seems like a skill well-suited for addressing the issues of context. Further, information architecture is set to adopt a holistic view of systems, users, and context – promoting awareness and discovery over efficiency in specific tasks.

If points of convergence between information architecture and context-aware adaptive systems are accepted, several questions are relevant for future inquiry: How can the respective fields be made more accessible? What aspects of each are most relevant to combine, compare and contrast? How

can researchers and practitioners meet for interdisciplinary cooperation? And in what application areas can such a cooperation be most beneficial?

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Footnotes

[1]. This paper will not attempt to reconcile all available definitions. For an historical overview of the field, see Resmini and Rosati (2011), Chapter 2.

[2]. It should be noted that Resmini and Rosati (2011) object to the word "inherent", even when not specifically considering context-aware adaptive systems. Resmini had already made his disagreement explicit in a blog post titled "Of Patterns and Structures" (2010). http://andrearesmini.com/blog/of-patterns-and-structures.

[3]. There are many different approaches, extending beyond computer science, such as the very readable overview by Rothrock et al (2002), published in Theoretical Issues in Ergonomics Science.

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