

# Context-Aware Artefacts: Current State and Open Questions from an IS Perspective

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## Abstract

*Context and context-awareness are being investigated in pervasive computing (PC) and human-computer interaction (HCI) for quite some time. More recently, context-awareness has also become a topic of interest in information systems (IS). Mobile services are among the topics that have shown to be of particular interest. Motivated by this growing interest we investigate what notions of context-awareness have been implemented in computational artefacts and whether these implementations actually meet the definitions of context that were identified as starting points in the respective research. Results of this investigation suggest that many implementations of context-awareness are driven by (technical) feasibility rather than actual user needs. Business applications, however, should be driven by user needs. Furthermore such applications need to be based on sound concepts and technologies. Our findings, however, suggest that there are issues that need to be addressed before we can expect "full" context-awareness. Based on these findings we discuss what this means to developers looking for technical foundations for their services. We also outline work that needs to be done in order to better understand context-awareness and its applicability in IS domains.*

## Keywords

Context, context-awareness, frame problem, social interaction

## INTRODUCTION

The concept of "context" is increasingly receiving attention in research areas different from those traditionally concerned with understanding context, such as linguistics and pragmatics (see Goodwin and Duranti (1992) for a broad overview). Among others, researchers interested in artificial intelligence, pervasive computing, human-computer interaction, and computer-supported cooperative work have begun to explore ways of making use of context to enhance products and services.

The idea behind making computational artifacts "context-aware" is that artifacts are enabled to sense the context in which they are being used such that they can adapt their functionality accordingly. An almost classical example for the potential benefit of context-aware artifacts is the idea of a context-aware mobile phone. Hull et al. (1997), among others, asked the intriguing question "Who really wants their mobile communicator to ring while in the midst of a theatre audience?" The expectation is that a context-aware mobile phone would not ring in a theater audience (there might be exceptions though). In other words, the idea is that a "context-aware mobile" would use context aspects, such as the user's identity, the user's location, and the user's current schedule, to determine the level of intrusiveness that would be appropriate when trying to notify the user of incoming calls. Notifications could range from ringing (quite intrusive) to buzzing or vibrating (less intrusive). The mobile even might suppress notifications of less important calls (not intrusive at all).

The growing IS interest in context and context-awareness is the motivation for this paper. Given the complexity of the topic we are keen to know what can reasonably be expected from context-aware artifacts in the near future. After all, business applications should be based on sound concepts and technologies. To this extent we review the literature regarding the notions of context-awareness that have been operationalized in computational artifacts and examine whether these operationalizations actually reflect the definitions of context that were identified as starting points in the respective research. The research approach we chose is a conceptual study approach which is an established way to conduct research in IS (e.g., Shanks et al. 1993).

We proceed as follows. First we set the stage by illustrating the recent IS interest in context and context-awareness. Then we focus on the operationalization of context in "context-aware" artifacts. We investigate what notions of context-awareness have been operationalized in computational artifacts and whether these operationalizations actually meet the (verbal) definitions of context that were identified as starting points in the respective research. Our findings suggest that there are two issues involved that are largely unresolved: the loss of the "generative" nature of context and the related emergence of the frame problem. Next we use the findings to argue that there are open questions that need to be addressed. The last section provides conclusions and an outlook on future research directions.

## RELATED WORK

Within IS we observe growing interest in using context for enhancing the functionality of mobile devices and the quality of services enabled by and delivered through such devices. At the Australasian Conference on Information Systems (ACIS), O'Brien and Burmeister (2002), among others, stressed that "*[m]atching of service characteristics to user preferences is still a key requirement [...] Adding the ability to determine the current location of the user at all times allows dynamic delivery of mobile services that are personalized on the basis of recorded preferences, location, context and relevant events as they occur.*" The growing interest of IS in mobile work is also reflected by Dawson et al.'s (2002) work presenting a framework and an associated context model for mobile work. Scheepers and Steele (2002) provide results of an empirical study indicating that mobile devices may change the social interaction between system users and their clients. The devices observed were not context-aware; later in this paper we will motivate however that the impact of context-aware devices might exceed the impacts observed already.

An approach to making use of context in order to provide users with exactly the information that is useful in a particular work situation has been explored by Gross and Prinz (2000). They created an "awareness information environment" to "provide users with information that is related to their current context and therefore of most value for the coordination of the group activities." Despite coming from computer-supported cooperative work (CSCW) their work is clearly related to determining "*recorded preferences, location, context and relevant events as they occur*" as under investigation by O'Brien and Burmeister (2002).

Rhodes and Maes (2000) provide an example from the realm of software agents. Their "just in time" information retrieval agents monitor the user's writing activities and continuously scan databases for information that might be relevant to the writing context.

In a way, software agents illustrate that context-dependent delivery of information is closely related to context-awareness. Software agents can be viewed as early (software-based) approaches to context-aware artifacts. Examples discussed by Maes (1994) include an agent for email handling and an agent for netnews filtering. Clearly, such agents would need a degree of context-awareness in order to be able to deliver what they promise.

## CONTEXT AND CONTEXT AWARENESS (AND TRICKS AND TRAPS)

In this section, we look at the "context" concept and shed light on some of the difficulties involved in understanding and modeling context. Then we review definitions of context found in the context-awareness literature and discuss how they were reportedly operationalized in computational artifacts. Based on the findings we identify what we call the "reduction step" and provide a critique of this often implicitly made step. Trade-offs involved in the reduction step, namely the loss of the "generative" nature of context and the related emergence of the frame problem, as well as open research questions will be discussed in the next section.

The related literature suggests that "context" is more like a concept than a precisely defined term. Goodwin and Duranti (1992), for example, argue that context is shaped by the specific activities being performed at a moment and this in turn influences what participants treat as relevant context. They summarize that "*it does not seem possible at the present time to give a single, precise, technical definition of context, and eventually we might have to accept that such a definition may not be possible.*" Using Bateson's (1972) metaphor of a blind man using a stick, Goodwin and Duranti illustrate that when analyzing context, it is crucial to take *as a point of departure the perspective of the participant(s)* whose behavior is being analyzed.

Agre (2001) explains the problem as such that people use the various features of their physical environment as resources for the social construction of a place, i.e., it is through their ongoing, concerted effort that the place - opposed to space- comes into being. An artifact will be incapable of registering the most basic aspects of this socially constructed environment. Accordingly, a context-aware artifact may fail annoyingly as soon as the system's (wrong) choices become significant. Similarly, Winograd (2001) states "features of the world become context through their use". In other words, something is not context because of its inherent properties but because of the way it is used in (human) interpretation.

It is reasonable to summarize that that the context phenomenon is closely related to the social construction of place. Robertson (2000) analyzed important aspects of this process in a setting often proposed as a domain for computational support: coordination of work during business meetings. As part of a workplace study in a software company, Robertson attended weekly meetings over a period of seven months, making separate video and audio recordings of relevant meeting activities. One of the questions to answer was what designers were doing during these meetings as the company intended to understand and support such collaborative activities. Robertson observed that the business situation was characterized by ongoing changes. These changes, however, are difficult to recognize. In particular, typical "context aspects" (see below) that could be sensed by currently available technology did *not* appear to undergo recognizable changes.

The 2001 Human Computer Interaction special issue on context-aware artifacts is an excellent point of departure when trying to understand how researchers try to operationalize context. In the anchor article, Dey et al. (2001) review several definitions of context. Their objective is to find a definition that is sufficiently broad to cover all relevant aspects of context but that still can be "operationalized" in computational artifacts, such as mobile phones or handheld devices. Dey et al. consider a definition found in Webster's Dictionary "*The whole situation, background or environment relevant to some happening or personality*" as too general to be useful in context-aware computing. In the end, Dey et al. come up with their own (since then frequently cited) definition: "[a]ny information that can be used to characterize the situation of an entity, where an entity is a person, place, or object that is considered relevant to the interaction between a user and its application, including the user and the application themselves.[1] Context is typically the location, identity and state of people, groups and computational and physical objects.[2]"

In this paper, we are especially interested in the step to the specific way how a definition of context is operationalized (in the sentence marked as [2]) from the verbal definition of "context" (in the sentence marked as [1]). This step is of particular interest as it can be found in most approaches to operationalizing context.

Discussions of approaches to operationalizing context typically start from broad definitions of context meeting the requirements of the application areas under investigation. Then, when actually operationalizing the definition of context, *specific aspects* of the definition are being selected to be "context".

Generally speaking, there is nothing wrong with such a reduction approach but as we will argue in the next section there are significant trade-offs if relatively static and observer-relative definitions of context substitute for a concept as dynamic as "context".

The reduction step is omni-present in papers exploring technical implementations of context-awareness. Dey et al. (2001), for example, make the step between (1) and (2) (see the above definition) when they reduce "[a]ny information that can be used to characterize the situation of an entity" to "*typically the location, identity and state of people, groups and computational and physical objects.*" Similarly, Hull et al. (1997) list identity, locations, companions, vital signs, air quality, and network availability as examples of context aspects. Gross and Prinz (2000) define an awareness context as "*the interrelated conditions in which something exists or occurs.*" 'Interrelated' denotes some kind of continuity; conditions are circumstances, such as time and location; 'something' refers to users, groups, or artifacts; 'exists' can refer the presence of a user; and 'occurs' denotes that an action is performed by a human or a machine (Gross and Specht 2001). In the end, however, the definition is reduced to human members of a context, physical locations related to a context, and artifacts of a context (Gross and Specht 2001).

O'Brien and Burmeister (2002) argue in a similar direction when following scholars in classical artificial intelligence (e.g., Lenat 1998) in their understanding of context as having twelve precisely defined dimensions. In addition they distinguish between "context-awareness" and "situation-awareness" arguing that "[...] *the ability to eliminate irrelevant, unnecessary and inappropriate messages and alerts automatically is not only dependent on context awareness. It also requires situation awareness.*" Context-awareness and situation-awareness appear to be closely related as "[d]etection of situations requires awareness of the context dimensions of absolute time, type of time, absolute place, type of place, culture, granularity, and local bindings of variables."

To sum up, it is reasonable to state that typically "context" is reduced to a number of aspects having the following characteristics:

1. the aspects are pre-selected to be "context" by developers
2. the aspects can be handled by the technology currently available to researchers (i.e., context aspects can be measured or are explicitly provided by users)

Clearly the approach is driven by real world constraints requiring researchers to make use of what is technically feasible (and currently available) rather than what would be "nice to have" (but hard to accomplish). However, from a research point of view and from a business point of view it is necessary to clearly state the trade-offs involved.

Most importantly, operationalizing context based on the reduction method discussed in the previous section involves as a trade-off that "context" is no longer created in the interaction with a situation. To the contrary, "context" then consists of pre-defined and well-defined entities. As a consequence, "meaning" and "relevance" of those aspects considered "context" is determined. Other -potentially relevant- aspects may not be included in the context description; currently irrelevant aspects may become relevant in the near future. In other words, the well-defined kind of "context" loses exactly what constitutes context in human interaction: "*features of the world become context through their use*" (Winograd 2001).

Furthermore, operationalizing a definition of context by pre-selecting aspects of the environment as "context" involves the frame problem (e.g., Pylyshyn 1987) which is one of the hard problems in classical representation-based artificial intelligence. Roughly, the frame problem is about what aspects of the world need to be included in a sufficiently detailed world model and how such a world model can be kept up-to-date when the world changes. The problem is that the real world is constantly changing, intrinsically unpredictable, and infinitely rich (Pfeifer and Rademakers 1991). Indeed, the frame problem has shown to be intractable in realistic settings (e.g., Dreyfus 2001). The frame problem is said to be a more technical problem but it can also be understood as an ontological problem as aspects of the world included in a world model determine the "understanding" of the world based on the model: facts not included in the model and not derivable from the model cannot be explained based on the model. This means that the frame problem in AI is directly related to artifacts trying to understand any notion of context.

## **RESEARCH ISSUES IN CONTEXT AWARE COMPUTING**

From a service-oriented perspective (e.g., usefulness, reliability) it is necessary to have a sound understanding of the current state of a new technology as well as a good understanding of what can be expected in the near future. Our literature review suggests that the situation regarding context-aware artifacts is diffuse. There is some exciting work going on and researchers are getting a better understanding of the difficulties involved in operationalizing context. There are quite a few applications that show sophisticated ways of making use of specific context aspects, such as location (now generally summarized as location-based services). However, regarding the full notion of context as explored in this paper there are hardly any applications that are "context-aware" in a non-trivial sense and that have been tested over extended periods of time. Testing in realistic setting is considered crucial. Abowd and Mynatt (2000), for example, argue that "[d]eeper evaluation results require real use of a [ubiquitous computing] system, and this, in turn, requires a deployment in an authentic setting. The scaling dimensions that characterize ubicomp systems-device, space, people, or time-make it impossible to use traditional, constrained usability laboratories."

Regarding the second major problem identified in the previous section, the emergence of the frame problem, there is not much suggesting that research on operationalizing context will succeed in overcoming the problem that context -implemented as a classical "world model"- is always limited (c.f., the qualification problem, the representational problem, the inferential problem, the ramification problem, the predictive problem). Of course, hardness of the frame problem does not suggest abandoning research on operationalizing context. It suggests, however, to keep in mind that computational artifacts may well fail when trying to recognize a situation and that there need to be ways how these situations will be handled.

The considerations presented so far suggest the following issues to be addressed more explicitly in research on operationalizing context.

### **Relation of the context definition and the context model that is being operationalized**

It seems that a lot of research on context-aware artifacts is implicitly based on the assumption that in some application domains "context" is not continuously changing and that it is therefore feasible to represent context in rather static data structures. Gross and Prinz (2000), for example, explicitly state that modeling application contexts is an integral activity within their awareness information framework. Accordingly, they outline questions, such as who is responsible for modeling contexts, how can contexts be kept up-to-date, and who is going to update contexts, as open research questions.

The discussion in this paper indicates the need for making explicit the assumptions underlying operationalizations of context definitions. This would help both understand and evaluate approaches based on these assumptions. Issues to be addressed would be, for example, which aspects of the environment have been chosen to be context, and why; and why other aspects were not considered to be context. Greenberg (2001) outlines that context is a dynamic construct; a related research question would be how specific operationalizations of context definitions account for these dynamics. Gross and Prinz (2000) explicitly state that they see users of their awareness environment as those who are responsible for updating contexts; others do not address this issue or they do not state their views as explicitly.

### **In what situations does operationalizing context work? Why?**

In the literature there are few examples of context-aware artifacts (exhibiting limited notions of context-awareness as discussed above) that have been used over extended periods of time. An early example is the active badge system (Want et al. 1992) which was used over several months. The system focused on location as context. Employees in a research lab were equipped with tiny badges indicating their location so that calls from

the lab's reception could be forwarded to the precise locations of the respective recipients. Later on, the system was extended to include additional context features (Want and Hopper 1992).

Ten years later, we know that despite some clear benefit the technology did not become a standard office feature. The discussion of privacy issues in Want et al. (1992) suggests that reasons for that were less technical problems but social acceptance problems.

Discussion of findings as detailed as in Want et al. (1992) would largely help other researchers benefit from the experiences made and get a better understanding of the social issues involved in fielding technology that makes use of context. Unfortunately such detailed discussion of findings is the exception not the rule.

### **In what situations does operationalizing context fail? Why?**

Problems that were detected when trying to operationalize context are rarely published although these insights would be particularly valuable. A notable exception is Greenberg (2001) reporting experiences with an always-on media space that tried to balance privacy and distraction concerns between physically separated users of these spaces. The idea behind the media space was that what people are able to see through a video channel is a reciprocal function of the distance between users and the displays. Being close to the display, users see and hear each other in full fidelity. With growing distance to the display, sound is turned off and images begin to blur. Experiences tell that the system worked well in settings, such as office environments, but was found inappropriate in more private settings where it may happen that the video channel inadvertently captures a flatmate in a state of undress.

Intelligent interface agents (e.g., Maes 1994), which were in the limelight of public and scientific attention in the middle of the Nineties, have not yet met expectations although some still expect agents to revolutionize human computer interaction (e.g., Lieberman and Selker 2000). Nwana and Ndumu (1999) stated that "[...] not much discernible progress has been made post 1994" but few papers address what the shortcomings of the technology really are.

In the context of system failures it is interesting to note that researchers in situated design (Pfeifer and Rademakers 1991) and participatory design (Greenbaum and Kyng 1991) have recognized for quite some time that it is problematic to make strong assumptions about users of systems and the contexts in which systems will be used. One of the lessons learned from the software engineering crisis is to get users continuously involved in the design and development of systems as well as to let users situate systems in their respective contexts. Kuhnt and Huber (2001) propose to see the history of software engineering as a sequence of crises, new challenges and corresponding approaches to address these challenges. The first software engineering crisis emerged after the founding years in the Sixties and was characterized by a rising error rate in programming. Techniques such as structured programming were used to overcome this and other more technical challenges. In the Eighties the introduction crisis followed which was characterized by the introduction of products not meeting user needs.

From this perspective, the challenge is not to make systems context-aware (as this necessarily involves shifting responsibility to the system from the user) but to build systems in such a way that users can easily adapt systems to their particular usage contexts.

### **Context-aware artifacts are here: what's next?**

We know from work on the task-artifact cycle (Carroll et al. 1991) that users adapt themselves to artifacts and vice versa. Recently, related research has been done in the area of mobile phones and technology appropriation (Howard et al. 2001). Youngsters have been observed to use (or not use) features of mobile phones to change certain aspects of their social life, such as the need to meet at specific times at specific places; mobile phones allow to meet 'on the run', fragmenting their lives (Carroll et al. 2001).

In the case of context-aware artifacts, it will be interesting to observe to what extent users adapt to the notions of context embedded in such artifacts; especially, if a notion of context does not meet what has been negotiated among peers in a situation. The results of the study by Scheepers and Steele (2002) can be interpreted such that context-aware devices will also have significant impact on the social interaction between system users and their peers.

A related question to investigate would be the benefit of providing explicit clues to help artifacts recognize context. Given that the latest mobiles feature built-in wireless network support and support for maintaining multiple behavior profiles, it would be easy to provide a basic infrastructure that reflects "context profiles" for a range of locations based on widely shared social norms. In a theater, for example, emitters located near the entrance doors could advise mobiles to switch to a pre-defined "theater audience" profile. As such profiles are to be determined by the owners of the mobiles, owners can still receive calls by setting their "theater audience" profile accordingly (and get blamed if mobiles exhibit unwanted noise). However, only a rough idea of what is

"appropriate" could be encoded. For example, theaters may be used for receptions or other events during which ringing mobiles would be tolerated. Such "exceptions from the rule" nicely indicate that the frame problem needs to be considered even in supposedly "static" domains.

## CONCLUSIONS

In this paper, we looked from an IS perspective at context and context-aware artifacts. By this we mean that we are mainly interested in what context-aware artifacts are offering right now and what can be expected in the near future.

A review of the context-awareness literature suggests that the typical approach to "operationalizing" the "context" concept is substituting (dynamically created) context for pre-defined selections of context aspects. We outlined that this "reduction step" involves two major issues, which are the loss of the "generative" nature of context and the related emergence of the frame problem. These issues have been identified to be contributing to the gap between vision and feasibility (Lueg 2002).

Until these issues have been resolved we would recommend focusing on services that are based on foundations that have shown to be reliable. Location-based services, for example, have already shown a high degree of reliability. Adding further dimensions to this established research direction seems to be more promising than trying to achieve "full" context-awareness.

Regarding the ultimate goal of "full" context-awareness, we have proposed a different way of asking questions about the nature of context and how to operationalize context. Respective questions are intended to complement experimental work and we expect that ultimately, answers to these questions will greatly help build systems that make appropriate use of context. Most of the questions we presented can only be answered empirically which means that further research in this area depends on analyses of experiences made when fielding context-aware applications.

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