Thomas R. Roth-Berghofer
Stefan Schulz
David B. Leake (Eds.)

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Modeling and Retrieval of Context

Second International Workshop, MRC 2005
Edinburgh, UK, July/August 2005
Revised Selected Papers

Springer

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Preface

Computing in context has become a necessity in modern and intelligent IT applications. With the use of mobile devices and current research on ubiquitous computing, context-awareness has become a major issue. However, context and context-awareness are crucial not only for mobile and ubiquitous computing. They are also vital for spanning various application areas, such as collaborative software and Web engineering, personal digital assistants and peer-to-peer information sharing, health care workflow and patient control, and adaptive games and e-learning solutions. In these areas, context serves as a major source for reasoning, decision making, and adaptation, as it covers not only application knowledge but also environmental knowledge. Likewise, modeling and retrieving context is an important part of modern knowledge management processes.

In addition, context can play a role in determining what information a system should provide. This is important for supporting the users of automated or intelligent systems, for tasks such as explaining how solutions are found, what the system is doing, and why it operates in a certain way. The methods applied and the advice given have to be explained, so that the user can understand the process and agree on decisions. Context is equally important for deciding when to provide uncertain or blurred information, e.g., when using a tracking system in situations for which either revealing the current position, or denying access to it, would have adverse effects.

In this wide range of applications, context is now more than just location. It is seen as a multi-dimensional space of environmental aspects, even including non-physical facets like emotions. Hence, models for representing context have evolved from using simple key-value pairs to using current methods and techniques derived from artificial intelligence and knowledge management, e.g., logic, object relationship models, and ontologies.

Appropriate context management methods are an important prerequisite for using this contextual information, e.g., to determine or assign a context to a situation, to cope with the fuzziness of context information and, especially because of mobility, to deal with rapidly changing environments and unstable information sources. Therefore, advanced models, methods, and tools are needed to provide mechanisms and techniques for structured storage of contextual information, to provide effective ways to retrieve it, and to enable integration of context and application knowledge. This entails the need for artificial intelligence mechanisms in context-aware applications.

Nine papers from the Second International Workshop on Modeling and Retrieval of Context, MRC 2005, held at the 19th International Joint Conference on Artificial Intelligence, in Edinburgh, Scotland, July 31–August 1, 2005, were selected and extended for this book. A major goal of the workshop was to study, understand, and explore the handling of context in IT applications. The following papers illustrate the state of the art of context modeling and elicitation as well as identification and application of context in different application scenarios.

Anders Kofod-Petersen and Jörg Cassens propose an interdisciplinary approach, using Activity Theory, to model context and then populate the model for assessing situations in a pervasive computing environment. Thus, they provide a knowledge-intensive context model from a socio-technical perspective.

Sven Schwarz introduces a context model for personalized knowledge management applications. The approach is based on an ontology that describes different aspects of a knowledge worker's information needs. Contextual information is gathered by user observation. The paper describes several implemented example applications.

Dominik Heckmann describes a service for modeling situations and retrieving contextual information in mobile and ubiquitous computing environments using Semantic Web technology. The paper introduces a General User Model and Context Ontology, called GUMO.

The next three papers describe layered architectures for context management, each with a different focus. The first paper describes a generic architecture, the second paper focusses on contextualized decisions, and the third paper deals with imperfection and aging of contextual information.

Kayu Wan, Vasu Alagar, and Joey Paquet describe and evaluate a generic, component-based architecture for developing context-aware systems. They propose a three tier model in which the first tier deals with perception, the second tier deals with context management, and the third tier deals with context adaptation.

The paper by Oana Bucur, Philippe Beaune, and Olivier Boissier discusses steps towards contextualized decisions. It addresses the problem of how to distinguish relevant from non-relevant context for a given task. The basis of the solution is a context definition and model for a context-aware agent that is able to learn to select relevant contexts. The three tier architecture comprises a layer of context sources, a context management layer, and a layer of agents that reason with context.

Andreas Schmidt deals with imperfection handling and controlled aging of contextual information. The paper presents a three layer model and its application to a context-aware learning environment for corporate learning support. The model distinguishes an internal layer with a context information base, a logical layer containing context feature values, and an external layer where the context information is applied.

The papers by Maria Chantzara and Miltiades Anagostou and by Aviv Segev (as well as by Bucur, Beaune, and Boissier mentioned above), present approaches to identifying appropriate contexts.

Maria Chantzara and Miltiades Anagnostou look into quality-aware discovery of context information. They introduce the Context Matching Engine which allows discovery of appropriate context sources for customized context-aware services.

The paper by Aviv Segev deals with identification of multiple contexts of a situation. The context recognition algorithm presented uses the Internet as a knowledge base. In the example described the real-time approach is successfully applied to ongoing textual conversations such as chats.

The paper by Michael Fahrmair, Wassiou Sitou, and Bernd Spanfelner proposes a generic mechanism for designing context awareness and adaptation behavior with formal methods. It introduces the concept of an adaptation context as a characterization of the system after carrying out an adaptation.

We hope that this research snapshot will be a useful foundation for future research on modeling and reasoning about context.

February 2006

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Using Activity Theory to Model Context Awareness

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Abstract. One of the cornerstones of any intelligent entity is the ability to understand how occurrences in the surrounding world influence its own behaviour. Different states, or situations, in its environment should be taken into account when reasoning or acting. When dealing with different situations, context is the key element used to infer possible actions and information needs. The activities of the perceiving agent and other entities are arguably one of the most important features of a situation; this is equally true whether the agent is artificial or not.

This work proposes the use of Activity Theory to first model context and further on populate the model for assessing situations in a pervasive computing environment. Through the socio-technical perspective given by Activity Theory, the knowledge intensive context model, utilised in our ambient intelligent system, is designed.

1 Introduction

The original vision of ubiquitous computing proposed by Weiser [1] envisioned a world of simple electronic artefacts, which could assist users in their day to day activities. This vision has grown significantly. Today the world of ubiquitous computing, pervasive computing or ambient intelligence uses visions and scenarios that are far more complex. Many of the scenarios of today envision pro-active and intelligent environments, which are capable of making assumptions and selections on their own accord.

Several examples exist in the contemporary literature, such as the help Fred receives from the omnipresent system Aura in [2, p. 3], and the *automagic* way that Maria gets help on her business trip in [3, p. 4]. More examples and comments can be found in [4]. Common to many of these examples are the degree of autonomy, common sense reasoning, and situation understanding the systems involved exhibit.

To be truly pro-active and be able to display even a simple level of common sense reasoning, an entity must be able to appreciate the environment which it inhabits; or to understand the situations that occur around it. When humans interpret situations, the concept of context becomes important. Humans use an

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abundance of more or less subtle cues as context and thereby understand, or at least assess, situations. The ability to acquire context and thereby fashion an understanding of situations, is equally important for artefacts that wish to interact (intelligently) with the real world. Systems displaying this ability to acquire and react to context are known as *context-aware* systems.

A major shortfall of the research into context-aware systems is the lack of a common understanding of what a context model is, and perhaps more importantly, what it is not. This shortfall is very natural, since this lack of an agreed definition of context also plagues the real world. No common understanding of what context is and how it is used exists. So, it is hardly surprising that it is hard to agree on the artificial world that IT systems represent.

Most of the research today has been focused on the technical issues associated with context, and the syntactic relationships between different concepts. Not so much attention has been given to context from a knowledge level [5] perspective or an analysis of context on the level of socio-technical systems [6].

This is the main reason for the approach chosen here. It should be feasible to look at how we can use socio-technical theories to design context-aware systems to supply better services to the user, in a flexible and manageable way. The approach should facilitate modelling at the knowledge level as well and furthermore enable the integration of different knowledge sources and the presentation of knowledge content to the user.

It can be stated that one of the most important context parameters available in many situations is the *activity* performed by an entity present in the environment. We therefore believe that by focusing on activities we will gain a better understanding of context and context awareness; thus bringing us closer to realise truly ambient intelligent systems.

Several approaches to examine activity have been proposed, like e.g. Actor-Network Theory [7], Situated Action [8] or the Locales Framework [9]. One of the most intriguing theories, however, is Activity Theory based on the works of Vygotsky and Leont'ev [10, 11, 12]. This work proposes the use of Activity Theory to model context and to describe situations.

Although our approach is general, in the sense that it is applicable to different domains, we are not trying to define a context model which will empower the system to be universally context aware, meaning it will be able to build its own context model on the fly. Although this would be a prerequisite for truly intelligent systems, IT-systems are usually designed for specific purposes and with specific tasks in mind where the system has to support human users. They are used by people with specific needs and qualifications, and should preferably adapt to changes in these needs over time [13, 14]. The aim of the work presented in this article is to assist the design of such systems which are tailored to support such kind of human work.

This article is organised as follows: first some background work on the use of context in cognition is covered. Secondly, some important concepts of Activity Theory are introduced. This is followed by an explanation of how Activity Theory can be utilised to model contextual information, including an illustrative example. In Section 5, the knowledge model, including context employed in this work, is described. Finally, some pointers for future work are presented.

2 Context in Cognition

The concept of context is closely related to reasoning and cognition in humans. Even though context might be important for reasoning in other animals, it is common knowledge that context is of huge importance in human reasoning.

Beside the more mechanistic view on reasoning advocated by neuroscience, psychology and philosophy play important roles in understanding human cognition. It might not be obvious how computer science is related to knowledge about human cognition. However, many sub-fields in computer science are influenced by our knowledge about humans; and other animals.

The field of Artificial Intelligence has the most obvious relations to the study of reasoning in the real world, most prominently psychology and philosophy. Since AI and psychology are very closely related and context is an important aspect of human reasoning, context also plays an important role in the understanding and implementation of Artificial Intelligence.

AI has historically been closely connected to formal logic. Formal logic is concerned with explicit representation of knowledge. This leads to the need to codify all facts that could be of importance. This strict view on objective truth is also known in certain directions within philosophy, where such a concept of knowledge as an objective truth exists. This can be traced back to e.g. the logic of Aristotle who believed that some subset of knowledge had that characteristic (Episteme). This view stands in stark contrast to the views advocated by people such as Polanyi, who argues that no such objective truth exists and all knowledge is at some point personal and hidden (tacit) [15].

Since context is an elusive type of knowledge, where it is hard to quantify what type of knowledge is useful in a certain situation, and possibly why, it is obvious that it does not fit very well with the strict logical view on how to model the world. Ekbia and Maguitman [16] argue that this has led to the fact that context has largely been ignored by the AI community. This observation still holds some truth, despite some earlier work on context and AI, like Doug Lenat's discussion of context dimensions [17], and the other work we discuss later in this section.

Ekbia and Maguitman's paper is not a recipe on how to incorporate contextual reasoning into logistic systems, but rather an attempt to point out the deficiencies and suggest possible directions AI could take to include context. Their work builds on the work by the American philosopher John Dewey. According to Ekbia and Maguitman, Dewey distinguishes between two main categories of context: spatial and temporal context, coherently know as background context; and selective interest. The spatial context covers all contemporary parameters. The temporal context consists of both intellectual and existential context. The intellectual context is what we would normally label as background knowledge, such as tradition, mental habits, and science. Existential context is combined with the selective interest related to the notion of situation. A situation is in this work viewed as a confused, obscure, and conflicting thing, where a human reasoner attempts to make sense of this through the use of context. This view, by Dewey, on human context leads to the following suggestion by the pragmatic approach [16, p. 5]:

1. Context, most often, is not explicitly identifiable.
2. There are no sharp boundaries among contexts.
3. The logical aspects of thinking cannot be isolated from material considerations.
4. Behaviour and context are jointly recognisable.

Once these premises have been set, the authors show that the logical approach to (artificial) reasoning has not dealt with context in any consistent way. The underlying argument is that AI has been using an absolute separation between mind and nature, thus leading to the problems associated with the use of context. This view on the inseparability of mind and nature is also based on Dewey's work. This view is not unique for Dewey. In recent years this view has been proposed in robotics as *situatedness* by Brooks [18, 19, 20], and in ecological psychology by J. J. Gibson [21].

Through the discussion of different logic-based AI methods and systems, the authors argue that AI has not yet parted company with the limitations of logic with regards to context. Furthermore, they stress the point of intelligence being action-oriented; based on the notion of situations described above.

The notion of intelligence being action-oriented, thus making context a tool for selecting the correct action, is shared by many people within the computer science milieu. Most notably the work by Strat [22], where context is applied to select the most suitable algorithm for recognition in computer vision, and by Öztürk and Aamodt [23] who utilised context to improve the quality and efficiency of Case-Based Reasoning.

Strat [22] reports on the work done in computer vision to use contextual information in guiding the selection of algorithms in image understanding. When humans observe a scene they utilise a large amount of information (context) not captured in the particular image. At the same time, all image understanding algorithms use some assumptions in order to function, creating an epistemic bias. Examples are algorithms that only work on binary images, or that are not able to handle occlusions.

Strat defines three main categories of context: *physical*, being general information about the visual world independent of the conditions under which the image was taken; *photogrammetric*, which is the information related the acquisition of the image; and *computational*, being information about the internal state of the processing. The main idea in this work is to use context to guide the selection of the image-processing algorithms to use on particular images. This is very much in line with the ideas proposed by Ekbia and Maguitman, where intelligence is action-oriented, and context can be used to bring order to diffuse and unclear situations.

This action-orientated view on reasoning and use of context is also advocated by Öztürk and Aamodt [23]. They argue that the essential aspects of context are the notion of *relevance* and *focus*. To facilitate improvements to Case-Based Reasoning a context model is constructed. This model builds on the work by Hewitt, where the notion of *intrinsic* and *extrinsic* context types are central. According to Hewitt, intrinsic context is information related to the target item in a reasoning process, and extrinsic is the information not directly related to the target item. This distinction is closely related to the concepts of *selective interest* and *background context* as described by Dewey. The authors refine this view by focusing on the intertwined relationship between the *agent* doing the reasoning, and the *characteristics* of the problem to be solved. This is exactly the approach recognised as being missing in AI by Ekbia and Maguitman.

Öztürk and Aamodt build a taxonomy of context categories based on this merger of the two different worlds of information (internal vs. external). Beside this categorisation, the authors impose the action, or task, oriented view on knowledge in general, and contextual knowledge in particular. The goal of an agent *focuses* the attention, and thereby the knowledge needed to execute tasks associated with the goal. The example domain in their paper is from medical diagnostics, where a physician attempts to diagnose a patient by the hypothesise-and-test strategy. The particular method of diagnostics in this Case-Based Reasoning system is related to the strategy used by Strat. They differ insofar that Strat used contextual information to select the algorithms to be used, whereas Öztürk and Aamodt have, prior to run-time, defined the main structure of a diagnostic situation, and only use context to guide the sub-tasks in this process.

Zibetti et al. [24] focus on the problem of how agents understand situations based on the information they can perceive. To our knowledge, this work is the only one that does not attempt to build an explicit ontology on contextual information prior to run-time. The idea is to build a (subjective) taxonomy of ever-complex situations solely based on what a particular agent gathers from the environment in general, and the behaviour of other agents in particular.

The implementation used to exemplify this approach contains a number of agents "living" in a two-dimensional world, where they try to make sense of the world by assessing the spatial changes to the environment. Obviously the acquisition of knowledge starting with a *tabula rasa* is a long and tedious task for any entity. To speed up the process the authors predefined some categories with which the system is instantiated.

All in all, this approach lies in between a complete bottom-up and the top-down approaches described earlier.

3 Activity Theory

In this section, we concentrate on the use of Activity Theory (AT) to support the modelling of context. Our aim is to use AT to analyse the use of technical artefacts as instruments for achieving a predefined goal in the work process as well as the role of social components, like the division of labour and community rules. This helps us to understand what pieces of knowledge are involved and the social and technological context used when solving a given problem.

First in this section, we will give a short summary of aspects of AT that are important for this work. See [25] for a short introduction to AT and [26, 27] for deeper coverage. The theoretical foundations of AT in general can be found in the works of Vygotsky and Leont'ev [10, 11, 12].

Activity Theory is a descriptive tool to help understand the unity of consciousness and activity. Its focus lies on individual and collective work practise. One of its strengths is the ability to identify the role of material artefacts in the work process. An activity (Fig. 1) is composed of a subject, an object, and a mediating artefact or tool. A subject is a person or a group engaged in an activity. An object is held by the subject, and the subject has a goal directed towards the object he wants to achieve, motivating the activity and giving it a specific direction.

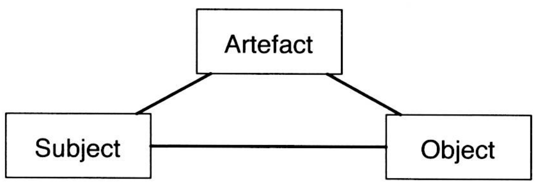

Fig. 1. Activity Theory: The basic triangle of Mediation

Some basic properties of Activity Theory are:

- **Hierarchical structure of activity:** Activities (the topmost category) are composed of goal-directed actions. These actions are performed consciously. Actions, in turn, consist of non-conscious operations.
- **Object-orientedness:** Objective and socially or culturally defined properties. Our way of doing work is grounded in a praxis which is shared by our co-workers and determined by tradition. The way an artefact is used and the division of labour influences the design. Hence, artefacts pass on the specific praxis they are designed for.
- **Mediation:** Human activity is mediated by tools, language, etc. The artefacts as such are not the object of our activities, but appear already as socio-cultural entities.
- **Continuous Development:** Both the tools used and the activity itself are constantly reshaped. Tools reflects accumulated social knowledge, hence they transport social history back into the activity and to the user.
- **Distinction between internal and external activities:** Traditional cognitive psychology focuses on what is denoted internal activities in Activity Theory, but it is emphasized that these mental processes cannot be properly understood when separated from external activities, that is the interaction with the outside world.