Context in Artificial Intelligence: II. Key elements of contexts

RUNNING TITLE: Context in Artificial Intelligence: Key elements

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Abstract:

Context is the challenge for the coming years in Artificial Intelligence (AI). In the companion paper [6], we present a view of how context is considered through the literature in various domains. In this paper, we present the main results of discussions at some workshops and the first conference focusing on the notion of context. We point out the opposition between two viewpoints on context, namely the Engineering and the Cognitive ones. We show that this opposition is only superficial because they do not consider context at the same level, one is at the level of the knowledge representation, the other at the level of the interaction between two agents.

Keywords: Context, knowledge representation, knowledge modeling, contextual knowledge, contextualized knowledge, reasoning

1 INTRODUCTION

Context plays an important role in a number of domains since a long time. This is especially true for activities where reasoning intervenes as interpreting data, predicting context changes, explaining unanticipated events and helping to handle them, and focusing attention.

The first works considering context explicitly are in Natural Language. For instance, Frege in 1892 identified three different contexts, ordinary, direct, and indirect, in which names can be used [19]. In an ordinary context, names have their customary denotation and sense. The direct context is what is now known as the use-mention distinction: word name (denote) other words. (In writing, quotation marks or italics are used for direct contexts.) In an indirect context, names denote their customary denotation and have an indirect sense that is different from their customary sense.

More recently, one of the main observation of the IJCAI-95 Workshop on Context in Natural Language Processing (NLP) is that context in NLP stays rather unexplored [23]. Consequences are serious. First, there is a theory-versus-practice gap. Second, context appears to be a huge bag of issues, virtually always closely related to the specific task at hand, domain, application, and the research problems of immediate interest to authors. Third, works addressing context problems clearly are too vague and do not address the specific questions about context. Fourth, one should not even attempt to unify the various notions of context as long as a consensus is not reached. However, there is an agreement on the fact that context provides constraints on reasoning, increases information content of natural language utterances, and facilitates learning. Such conclusions are similar to those in AI.

In Artificial Intelligence, the lack of explicit representation of context is one of the reasons of the failures of many Knowledge-Based Systems (KBSs) [9]. The failures concern the exclusion of the user from the problem solving, the misuse and lack of knowledge in knowledge-based systems, and the impossibility to generate relevant explanations. All these failures arise because knowledge-based systems have been developed out of their working environment with a user. The most important failure is then the **lack of contextual dimension of knowledge-based systems** [5].

One reason is that users develop personal practices not introduced in the systems. For example, in working places, executive humans develop working ways (strategies, relationships among them, etc.) to reach the efficiency that decision-makers wait when they design the work. Part of their practical solving of problems is not coded [22]. Such a know-how is generally elaborated case-by-case in nonwritten rules. A nonwritten rule takes into account the real context of the problem at a given moment. Such "makeshift repairs" permit the executive actors to reach the required efficiency. This is a manner to reach the solution whatever the path followed is. The validation of such nonwritten rules is more linked to the result than to the procedure to reach it. Knowledge-based systems do not possess such contextual knowledge.

Nowadays, one notes an increasing interest for context. Since 1991, several scientific events in Artificial Intelligence dealt specifically with context, and a number of works consider the context explicitly from the level of the modelling of the domain knowledge to the level of the programming languages. The modelling, representation and use of context is the challenge of the coming years, especially when we now face very complex problems, large knowledge bases and multimedia means.

Hereafter, the paper is organized in the following way. Section 2 presents a summary of discussions at workshops in Artificial Intelligence (results at two workshops in human-computer interaction are presented in [7]). We discuss in Section 3 the two sides of context and in Section 4 the way in which context is applied.

2 SUMMARY OF DISCUSSIONS AT WORKSHOPS IN AI

2.1 Introduction

The two workshops on context at IJCAI-93 and IJCAI-95 (the proceedings are available as Research Report 93/13 and 95/11 at author's laboratory, and a report on the IJCAI-93 workshop is given in [7]) were organized with an electronic discussion before the workshops. This permitted to focus during the one-day workshops on hot topics and problems not solved during the electronic discussion.

We present first, the results of the electronic discussions prior the two workshops. Then, we give the conclusions of the one-day workshops. Finally, we present the conclusions obtained at the First International and Interdisciplinary Conference held in 1997.

2.2 Discussions prior workshops

On the basis of the received papers, the program committee selected four topics on context for discussion before the workshop: (1) the position of context, (2) the elements of context, (3) the representation of context, and (4) the use of context.

2.2.1 Position of context

The position of context concerns what context is with respect to other entities, such as situation, behavior, point of view, meaning, relationships among agents, discourse, dialogue and application dependency. Three examples illustrate the position of context. First, in explanation, the use of the context allows one to tailor a generated utterance to a user. Second, in knowledge acquisition, the explicit use of context limits the domain of validity of the acquired knowledge and indicates its correct moment of use. Third, the explicit use of the context in diagnosis reduces the search to a smaller state space. A key question here is whether the process of achieving context--contextualization as introduced by Edmondson and Meech [16]--or the resultant state is of primary concern.

2.2.2 Elements of context

The elements of context include objects of the domain and the task at hand, as well as the organization of the elements, the mechanisms for managing them, and the manner in which these elements can manage domain knowledge. Further, what really are the dimensions of the context such as time, space (itself multi-dimensional), and variables of the system (some, for example, could be dependent on user profiles or models). Questions that arise from attempting to define the elements of context include: Is it sufficient to add a time dimension to account for context? Does context simplify or complicate the construction of a knowledge base? Is context nested in chunks of knowledge or, conversely, are chunks of knowledge nested in context(s)? Is context an object of the domain? Can we decontextualize knowledge (that is, move from one context to an outer context, as introduced by McCarthy [27])? What are the links between the process of contextualization and decontextualization? What are the links between the external situation and the internal components of the context?

2.2.3 Representation of context

For the representation of context, one must examine the relation between the representation of context and the choice of formalism for representing and reasoning about a domain. Some believe that logic is the correct formalism, but others believe that semantic networks or conceptual graphs are better. Many formalisms are candidates. Some questions that arise from attempting to represent context include: What are the possible formalisms that seem to allow explicit representation of context? What are the comparison criteria of two formalisms with respect to context? What are the advantages and drawbacks of each of the possible formalisms? For a given formalism, which aspects of context are easily represented? Which ones are impossible to tackle? Such questions are important since it seems necessary to define what a context is with respect to the representation formalism that is used. However, it appears that the characteristics, the properties and the like are dependent on the formalism that is chosen. Thus, it is difficult to have an abstracted view of what a context is, that is at a conceptual one.

2.2.4 Appraisal

A priori, there seems to be two main uses of context: (1) to internally manage knowledge chunks and (2) to manage communication with a user. Some questions that arise in attempting to typify the use of context are the following: Which representation formalisms allow reasoning in context? How do we use context to extract and present the relevant chunks of knowledge? Is context more important in some domains (for example, linguistics) than in other ones? Is the use of context definable as an activity or a process of contextualization? What are the links between internal and external management of knowledge?

2.3 Results of the one-day workshops

2.3.1 Introduction

A key factor in studying any of the aspects of context is whether one's view is that of a cognitive scientist or that of an engineer building a system to solve a particular problem. The *cognitive science view* is that context is used to model interactions and situations in a world of infinite breadth, and human behavior is key in extracting a model. The *engineering view* is that context is useful in representing and reasoning about a restricted state space within which a problem can be solved. On closer examination, one realizes that the engineering view is subsumed by the cognitive science view. Thus, participants from the two disciplines face similar problems in defining and using context and can share ideas in researching a solution.

Through participant interaction it rapidly became clear that one cannot consider any of the four aspects of context in isolation. Moreover, it is difficult to speak of context independently of its use: We cannot speak about context out of context. Also, participants are interested in context in very different domains (logic, communication, knowledge acquisition, explanation, diagnosis, and so on).

Thus, we reduced the objectives of the workshops to clarify basic definitions and highlight differences in the participants' views on context. In the following subsections, we summarize the views and insights into context that were achieved by the workshop participants.

2.3.2 Context and its use

Context is used in a number of domains. Indeed, it appears that there are as many contexts as use of context since the notion of context seems inseparable from its use. Most of the papers in the Proceedings (and elsewhere [25, 26]) discuss aspects of context that are different. Thus, an abstraction of the various considerations on context at a conceptual level is difficult. One must first define what we want to do with a context in a given situation, even if we assume that we are always moving between contexts. (For example, must we speak of a discrete space of contexts or a continuous one?)

The use of context seems particularly important for a number of activities, including predicting context changes, explaining unanticipated events and helping to handle them and focus attention. Indeed, one can state the fact that the activity in which one is engaged is itself the process of data contextualization. Context is what gives meaning to data, and "contextualization" is the process of interpreting data, transforming data into information. Moreover, the aspects of an agent's context that are relevant to an agent's activity can change as a function of the agent and the activity itself.

Cognitive processes are contextual. They depend on the environment (a part of the context) inside which they are carried out. Thus, from a cognitive point of view, the context of communication in human-human dialogue can be defined as a set of transitory mental representations that are dynamically built by people during the interaction from the external situation that they perceive and from their knowledge, beliefs and other characteristics. These transitory representations are of the past dialogue, the task that they are performing, the spatiotemporal situation, the psychosocial situation (representation of the other, of the social situation, and so on). They are selected according to their relevance in dialogue management, that is, to interpret what the other is saying and allows the other to interpret what we are saying (e.g. the process of contextualization). Thus, the interlocutors assume that they share a large part of the dialogue context, but actually, they do not share exactly the same knowledge and characteristics and, consequently, the same activated context. Every participant then has her/his own vision of the assumed shared context, and these differences might not affect the communication process, although sometimes, the differences are too important, and a communication failure occurs. We can try to represent the context for man-machine communication needs, but we can never be sure of the context that a human interlocutor really has in mind during a dialogue.

2.3.3 Situation and Current Context

The question of knowledge in context expands to its fullest scope in physically situated agents. As a preliminary convention, one can propose to call *situation* the entire setting of a physical environment, the agent(s) therein, and what mental stuff within the latter. The *reasoning environment* is that mental stuff inside an agent, which at a given moment is the active background for its reasoning activity. The *situation image* is the portion of the reasoning environment that constitutes the agent's actual mental image of the situation. Note that the notion of a reasoning environment captures much of what many (but not all) might call context.

When trying to arrive at a comprehensive theory of situations, reasoning environments, and situation images, one faces some hard problems, three of which are the horizon, the system, and the typology problems. The *horizon problem* states that situations and reasoning environments have no definite boundaries. The *system problem* states that the situation and reasoning environment cannot be isolated but form an interdependent, incessantly interacting system. The *typology problem* states that situations--and reasoning environments along with them--are forever evolving in a qualitatively productive way and therefore, cannot be reified and predescribed in a situation typology.

Another important and related aspect of the context problem is establishing the current context. The current context is sometimes considered as a combination of different contexts. For instance, there is the context set of the application and that of the user. However, it appears that the most important context is that of the interaction, as shared by all participants in the interaction. All other contexts are either private contexts [11] or interaction context.

2.3.4 Context and Reasoning

Context appears to be essential for all reasoning tasks and real-world problems. The use of the context in expressing reasoning may allow the exploitation of various forms of reasoning, such as nonmonotonic reasoning (within each context), reasoning about situations, approximate reasoning, and a solution to the qualification problem, abstract reasoning, and metatheoretic reasoning [20]. A context has also been considered as a frame of reference for the interpretation of information both input to, and derived from, reasoning.

However, it is not clear if we must consider either reasoning within contexts (the reasoning environment) or the use of context for representing reasoning. Context may limit the domain in which the reasoning applies For example, in reasoning about autonomous agents in cooperative, distributed problem solving, one must emphasize that contextual knowledge is crucial for solving real-world problems (for example, controlling an autonomous underwater vehicle [32]). Here, the role of contextual knowledge is to help an agent behave quickly, automatically, and appropriately for its current problem-solving situation. Examples include (1) biasing situation assessment by using top-down predictions about what the sensors are seeing, (2) modulating actions by setting behavioral parameters and automatically activating and deactivating goals based on the context, and (3) helping to choose actions appropriate for goals in the context.

Context may also be considered as a mechanism for managing, organizing or reasoning about knowledge. One advantage to making context explicit in a representation is the capability of inference within and across contexts, thus explicitly making the change in the reasoning across contexts. Context-sensitive reasoning can also be seen as a generalized form of case-based reasoning.

A central issue associated with the study of context is the relation between contexts and their organization. Contexts are related to each other: A context is defined in another context. Although contexts are related to each other in the basic definition, there are relations that may lead to an efficient management of movement from one context to another. For instance, using bridge rules, you can localize facts and reasoning to a single context before moving to another.

2.3.5 Context and Knowledge

Context provides a principled way to cluster, partition and organize knowledge and its dimensions. This partitioning becomes quite relevant when contextual knowledge is integrated into problem solving, such as when navigating troubleshooting hierarchies [1].

One can reuse knowledge across contexts. This knowledge must be decontextualized, permitting one to abstract a piece of knowledge from contexts into a more general context that cover the initial contexts.

However, it is not clear what the relationships between context and knowledge are at the level of their elements and at the level of their structures or organization. One needs to distinguish between having context-sensitive knowledge and knowing what the context is. For example, a robot may know that there is a pop can in front of it now without knowing where it is, what time it is, etc.

2.3.6 Components of Context

What is taken to constitute a context typically depends on the type of use one has in mind. In natural language understanding, it involves features of the discourse situation, such as speaker, hearer(s), time, and place, as well as the dialogue history and mental state of the participants. In large knowledge-based systems, context is mainly seen as a mechanism for partitioning the knowledge base. In situated action it covers actor, time, place, and objects involved; relevant background constraints on the situation (for example, structured lighting in robot vision); and background cultural assumptions, such as the individualization scheme.

The components of the current context that play a role in determining the context include much implicit, or background knowledge. Making such implicit knowledge in the current interaction explicit would permit one to include this contextual knowledge in bases of "contextualized knowledge."

However, this is not an easy task. The analogy of the frame problem was proposed, which involves dynamically modeling side effects of the actions taken in the world by making corresponding modifications in the database that represents the state of the world as far as a system is concerned.

2.3.7 Context and Representation

To select a formalism to represent context, one must consider how to link contexts with knowledge and link contexts with other contexts. Various formalisms explicitly represent context in system building including, logic, rule sets, conceptual graphs and semantic networks [1]. Rule sets are easy to encode but hide some of the control knowledge that link contexts. Conceptual hierarchies, subsumed by conceptual graphs, are often used in diagnosis since they obviate control knowledge and localize contextual knowledge to a single concept linked to other concepts. Semantic networks are also subsumed by conceptual graphs and allow for a variety of relations to link concepts that are directly taken as contexts.

Other approaches have also been proposed for representing a context: a packet of knowledge pieces (somewhat related to conceptual graphs), a set of preferences, a window on a screen, an infinite and only partially known collection of assumptions, a list of attributes, the product of an interpretation, and a collection of context schemas.

However, it is again not clear if the notion of context is separable from the representation formalism. In addition, it is not clear if a single representation is adequate. One result of the workshop discussion is that formalisms for representing context are strongly dependent on modelling requirements of context. Some of the key conflicts by participants at the workshops include some basic and quite divergent views: First, context can always be represented in well-defined domains. Second, context can partly be represented in narrow domains (e.g. diagnosis). Third, context can never be represented from a cognitive science view. Fourth, context can be represented without knowing what the context is. Fifth, context does not need to be represented since we only need to model the process of achieving context.

Some energetic discussion focused on the view that context does not need to be represented because we only need to model the process of achieving context, namely contextualization.

2.4 Results of the first conference on context

The First International and Interdisciplinary Conference on Modeling and Using Context in Real-World Applications, CONTEXT-97, held at the beginning of 1997 (Proceedings are published by the Federal University of Rio de Janeiro, Brazil, and a report on the conference is given in [8]). As a first conclusion of the discussion at this conference, one notes that logic has a top-down approach of context (from theory to applications), while applications imply a bottom-up approach of context (from the application to a modeling of context). Linguistics has an intermediary position, dealing with a real-world application (text or discourse) with theoretical tools developed in logic.

However, if logic and natural language processing are relatively close (at least by the formal approaches), the problems treated in these domains appear quite different from problems in real-world applications. Clearly, there is a deep gap between the viewpoints of Engineering and Cognitive Science. The gap that had been identified in previous events is stressed at this conference. It was due to the interdisciplinary dimension of the conference. However, if every one acknowledges the gap, clearly each one wants to know what is done in the other side of the gap to benefit of the results obtained rather than to attempt to fill the gap.

Some concerns emerge from the different works presented at CONTEXT-97. First, context, or contextual knowledge, contrains a problem solving without intervening directly in it. This observation is close from the view of Natural Language. Second, context is a means to manage knowledge bases, avoiding redundancy and optimizing retrieval. Third, the variety of definitions of context can be explain by the fact that one speaks of context without expliciting the level at which one is. The works of Bremond and Thonnat [2] and Brezillon et al. [10] give strong arguments for this. Four, the relationships between contextual and contextualized knowledge give a new vision of context, reconciling positions on discrete versus continuous context, for example. Five, making context explicit may permit to provide user with relevant explanation, to incrementally acquire knowledge. This is the first step toward a real understanding of context.

3 THE TWO SIDE OF THE CONTEXT

3.1 Introduction

The lack of consensus appears because the nature of context is considered either as static or dynamic, discrete or continuous, knowledge or process. An important question is: Is context known a priori or a posteriori? Considering context known a priori supposes that it may be modeled in a discrete representation and is static. Conversely, considering context known a posteriori implies that context is dynamic and can be modeled only during a problem solving (or interaction). The two diverging positions arise from the consideration of context at the level of either the interactions among agents or the knowledge representation.

3.2 Cognitive and engineering points of view

The notion of context is dependent in its interpretation on a cognitive science versus an engineering (or system building) point of view, the practice viewpoint versus the theory one. The *cognitive science view* is that context is used to model interactions and situations in a world of infinite breadth, and human behavior is key in extracting a model. The *engineering view* is that context is useful in representing and reasoning about a restricted state space within which a problem can be solved. On closer examination, one realizes that the engineering view is subsumed by the cognitive science view [7]. Thus, the different disciplines face similar problems in defining and using context and can share ideas in researching a solution. Once such a distinction between Engineering viewpoint and Cognitive viewpoint is made, one can achieve a kind of consensus on the aspects of context.

3.3 Static versus dynamic contexts

According to the engineering viewpoint, the context is static and considered at the level of the knowledge representation. As a consequence, there is a discrete number of contexts and the interest is on the management of contexts (e.g., see the lifting and bridging rules, and the algebra on contexts above). Static contextual knowledge is attached to the domain knowledge, and may be described in knowledge bases. The static part of the context is what may be coded at the design time or at the beginning of a session (e.g., the file '.profile' under UNIX). Along its dynamic aspect, part of the problem is linked to the changing nature of context in time, by elaboration and shift [12]. If it is (relatively) easy to represent the static aspect of context, the dynamic aspects of context must be considered during its use, say, a problem solving.

Thus, one must account for both the **static aspect** (knowledge that remains constant throughout the interaction) and the **dynamic aspect** (knowledge that changes throughout the interaction) of context. The changing knowledge of a context and the movement between contexts would be managed by independent but related mechanisms.

3.4 Implicit versus explicit contexts

Contextual knowledge acts as a filter that defines, at a given time, what knowledge pieces must be taken into account (made explicit) from those that are not necessary or already shared. A context is a structure, a frame of reference, that permits to do not say all the things in a story.

For example, "At his birthday's party, Paul blew up the candles." It is not said here there was a birthday cake because it is clear for everybody. Such a piece of knowledge is supposed to be a part of our social inheritance. There is a French movie call 'Le Chat' (the cat) presenting the life a husband and his wife living together since 40 years. Knowing each very well the other, they had severely limited their communication. For instance, with a light movement of the chin toward the cupboard, the husband asks implicitly "Can you please darling give me the salt that is in the cupboard." With a computer system, however there is a compromise to find between the need to store a large number of information pieces for a tailored presentation of the answer to the user's question and the limited capacities of computer memories.

In the SEPT application [3], the knowledge engineer discovered very late that equipment in a extra-high voltage substation function only when there exists a fault on the network. It was so evident that the expert had never expressed this contextual information before a conflict arose with the knowledge engineer. The expert had compiled this knowledge that became implicit when explaining the functioning of a piece of equipment. Other implicit knowledge in the SEPT application is: protective relays see effectively the fault to function, transmission cables transmit correctly signals from equipment to the central printer, the fault concerns the substation and does not occur in next substations.

This supposes that people share knowledge. However, it is frequent that the context--the frame of reference--must be built for the listener. For example, I may say to a person: "I heard a lion roars in my office this morning" (called hereafter CKo, CK standing for Chunk of Knowledge). It is self-explanatory for a person that knows me. If the person is surprised (i.e. the person has some trouble with CKo and may suppose that I am speaking of my boss), I must introduce different pieces of knowledge to be shared with the other: "I work in a university near a zoo that I can see from the window of my office. There are lions in the part of the zoo that is near the University. I often hear lions roar. It just was the case this morning." Here, CKo is introduced after various other CKs are first presented. Note that I still keep other pieces of information implicit, e.g. the window of my office was opened, there was no car traffic in the street between the University and the zoo. We thus make explicit the minimal quantity of information, others being supposed shared. The former person knows these knowledge pieces (that I work in a university near a zoo, that I can see the zoo from my office and that there are lions in the zoo).

Once a part of the interaction context only contains knowledge pieces that are shared, i.e., knowledge pieces are structured in a well-defined way, the structured pieces are then compiled in a single knowledge piece by both participants. That knowledge piece then will be recalled similarly to a pointer and explicit knowledge becomes implicit (shared) knowledge for the participants.

3.5 Contextual knowledge and contextualized knowledge

Contextualized knowledge is knowledge that is explicitly considered in the problem solving. Contextual knowledge intervenes implicitly in the problem solving, often as constraints. Consider the two following examples.

Example 1. Operators that ensure the monitoring of the distribution of water in Paris had noted that there was a peak in the water consumption late each evening. The peak was reproducible every day but not predictable because not exactly at the same time. After an inquiry, they discovered that persons use water for domestic needs (drink a glass of water, wash dishes, pour water on flowers, go to the toilets, etc.) during the advertisements introduced in the movie at the TV (at that time, France had only three channels). The introduction of advertisements in the movie depends on the organization of the scenario. Such a knowledge (the link between the peak of consumption and the advertisements at the TV) has a contextual nature for the water distribution.

Example 2. A similar situation had been noted for the distribution of electricity. The variations of the electricity consumption have been well studied, the peaks of consumption well identified and planned in advance. The main peak corresponds to the interval of time during which people go back to home, prepare the meal, and so on. This is so well known that the European power systems companies play with the different timing of the consumption peaks in each European country to import electricity and export their electricity production according to their off-peak hours.

In both examples, contextual knowledge is used to constrain the problem solving (water and electricity distribution). In the first example, it is difficult to account for (and use in a computer) the contextual knowledge--the time of advertisements at the TV--has an unpredictable nature because advertisements are not at exactly at the same time every evening, even if it is (too much) repetitive each day. Thus, one needs to look for this contextual knowledge when needed in the problem solving. Such a contextual knowledge concerns the dynamic aspect of context. In the second example, the contextual knowledge--people go back to home--is predictable with a good accuracy. Such contextual knowledge can be used in the planning programs of the electricity production. Thus, the contextual knowledge becomes operational (use in a system) and then contextualized knowledge.

However, the situation is not so simple. A piece of knowledge obtained at one step of the problem solving--a piece of contextualized knowledge--can be contextual knowledge at a following step. For example, the user's identification at the login time (contextualized knowledge) constrains after the available functionalities of the system for that user. Such a knowledge piece is first in the focus of attention (contextualized knowledge) and after acts as a filter of user's accesses at functionalities of the system (contextual knowledge).

This show that part of the users' feedbacks may be encoded by the designer because required improvements are general, repetitive and static. However, it will have always a part of users' feedbacks that are specific, depending in time on the task at hand, the conditions in which the task is accomplished, etc. For example, users do not all wish the same type of warning (and may change of advice along the software use becoming increasingly knowledgeable with the software): an alert window, a sound, a special icon, or any combination of them. Thus, an efficient system, during its interaction with the user, must tailor its behavior according to the user's reaction. For doing this, the system must manage some contextual information on the interaction.

The successive versions of a piece of software take into account for users' feedbacks and show the importance of a user-centered approach. However, what may please at a part of users will not please at another part. For example, the MacIntosh Operating System 7.5 provides a support at three levels when the user wants open an item: (1) a folder containing the last documents open whatever the application is; (2) a folder containing the last applications opened;

and (3) a folder containing the last servers visited. This improvement implies some assumptions about the way in which users work. When one opens a file, say a text file, in a given personal folder and one wishes transfer information from that file to another one in the same folder, one is obliged to follow the path from the recent-document folder to the other document, when previous versions started from the current folder. Indeed, users avoid this by a double click directly on the document to open it from the desk.

4 APPLYING CONTEXT

4.1 General characteristics

There is a consensus on the fact that **context is inseparable from its use**. Context is considered as a shared knowledge space that is explored and exploited by participants in the interaction. Such shared knowledge includes the history of all that ensured over an interval of time; the overall state of knowledge of the participating agents at a given moment; the small set of thing they are attending to at that particular moment. Other elements intervening in a context come from the domain (e.g. problem solving, task at hand, events, instantiated objects and constraints, the knowledge inferred by the system), the users (e.g. goals, expertise, beliefs, learner's profile, value assignments), their environment (e.g. organizational knowledge, corporate memory), their interaction with a system (e.g. transaction history, plans for the future, attention-focusing information). However, context lacks a recognizable unifying characteristic and is often the generalization of an infinite and only partially known collection of assumptions [27]. This is partly because the world cannot be objectively and exhaustively described; cultural or social circumstances cannot be reduced to a set of facts and procedures [24, 13].

The **context permits to guide the focus of attention**, i.e. the subset of common ground that is pertinent to the current task. The focus of attention is defined as the immediate context, whilst the common ground (or common context) was seen as being the mutual context that already exists between the agents [25]. An interesting point is that one can change of context to solve a problem that is not obvious in the immediate context.

Context permits to make reasoning local [20]. One of the strong stance of

Giunchiglia at the IJCAI-95 workshop was that "contextual reasoning is local reasoning." This stance is compatible with the various communications in various domains (nonmonotonic reasoning, robotics, pattern recognition). Expressing reasoning through context use may allow the exploitation of various forms of reasoning within distinct contexts, such as nonmonotonic reasoning, reasoning about situations, approximate reasoning, etc. With separate contexts, reasoning in one context may influence reasoning in other contexts.

4.2 Discrete aspect of context

A general approach for creating a context is to capture local contexts and generalize them. This permits to lift the relevant axioms from local theories in the new context, enter this context, and solve the problem. There are various ways of getting new contexts from old ones: by specializing the time or place, by specializing the situation, by making abbreviations, by specializing the subject matter, by making assumptions and by specializing to the context of a conversation.

Creating a context from existing contexts, it is possible to establish a hierarchy of contexts where a formula relating two contexts involving contextual assumptions is itself in a context [21]. The interest of a context hierarchy is that, working on an object in one context, something may be derived about that object in another context. The two contexts may use different vocabularies, and the treatment of the object may be easier in one context than another.

Entering (and exiting) a context serve two purposes. The import rules allow a fact about an object to be added to the object's description. It enables a simulator to import messages into a description. The export rules allow encapsulated information to be taken outside the context of an object. This permits to provide focus to speed up problem solving behavior and a context for the interactions with the system [21]. The new information then could be combined with the previous description to form the updated description [31].

However, there is a compromise to find between the cost and the utility of a context: Context analysis must be less time-consuming than the brought improvement [14]; Adding a new context to an existing conceptual graph requires major reorganization of the position orientation of existing contexts [17]; and It may have a potential combinatorial explosion of contexts [32, 33].

Moreover, the assumption of creating a context from existing ones, which permits interesting theoretical developments, is difficult to hold in practical situation because if we know that contexts exist, we cannot formalize them, mainly because they refer themselves to other existing contexts recursively. Facing a real-world problem, we are obliged to have an opposite approach, identifying the current context directly in an empirical way, and try to establish links with known contexts.

4.3 Continuous aspect of context

McCarthy [27] says that for using knowledge across contexts, one needs a process of decontextualization, permitting one to abstract a piece of knowledge from contexts into a more general context that cover the initial contexts. Conversely, Edmondson and Meech [16] suggest that the concept of "context" would be most preferably understood as a process of **contextualization**. Information is the process of contextualizing data, and this contextualization process involves both the immediate data, the history of data (e.g., what has preceded a word in a text or an utterance, or visual information in the case of a sign), and the knowledge already possessed by the recipient (i.e., mental models, general knowledge, etc.). Context then may typically be viewed as the environment of communication which enables the intended meaning to be ascribed by the recipient of the data. Edmondson and Meech give the example of a pilot in a cockpit, facing hundreds of captors. Few data provided by captors are transformed by the pilot into information, according to the immediate context (e.g., a flight in normal conditions or entering a turbulence zone).

However, although empirical evidence clearly shows that recall is much better in contexts similar to the context where the information was acquired, recall of decontextualized information is possible and even desirable in problem solving. Sandberg and Wielinga [30] give the example of the Newton's law (F=ma) that one recalls under its abstract expression, not in all the situations where one has applied it.

4.4 Some applications

Turner [34] associates context-sensitive reasoning and fuzzy reasoning. The meaning of a fuzzy "linguistic" value such as "deep" depends very much on what the current context is. In this approach, a reasoner uses information about the meaning of fuzzy values contained in contextual schemas (c-schemas), which are knowledge structures representing kinds of problem-solving situations. The work is part of the Orca project; Orca being a schema-based, context-sensitive reasoner whose domain is intelligent autonomous underwater vehicle control. Orca deals with three types of context: the static context (portion of the agent, its environment, and its knowledge unlikely to change over the course of a mission); the dynamic context (features of the agent, its environment, and its knowledge that do change during the mission); and the ephemeral context (established by the focus of one of the Orca's module reasoning). Fuzzy information interacts with each of these contexts.

Ozturk and Aamodt [28] present a model of context based on the roles and elements of various context types. Two important roles are relevance and focus. Context plays an important role in two reasoning tasks: memory use and action planning. They propose in problem solving a distinction between internal and external context types. Such a distinction permits to reflect the nature and demand of the process that takes place during learning and remembering, and the ground facts that happen to exist in a situation. Internal context imposes perspective through the problem solving goal, which in turn leads to a more focused and efficient reasoning process. External context imposes constraints for choosing a method, a specific line of reasoning, which in turn leads to a more relevant and quantitatively better solution. The authors have developed their ideas in clinical diagnosis. Contextual information permits to provide relevant explanations of cases.

Brézillon et al. [10] present a context-based representation of knowledge in the domain of subways to support operators in their context-based solving of incident on subway lines. The key of their representation is based on a distinction between contextual knowledge and contextualized knowledge. Contextualized knowledge is directly used at a given step of the problem solving, when contextual knowledge constrains the problem solving without intervening in it directly. Moreover, contextual knowledge can be organized in layers around the contextualized knowledge according to the onion metaphor. Contextual knowledge also ensures a link between the different steps of a given incident solving and across different incident solvings. Thus, if contexts at the level of problem-solving steps constitute a discrete set of contexts, there is a unique context at the level of the problem solving itself that evolves continuously along the solving.

Brémond and Thonnat [2] study the representation of context in knowledge-based systems in scene interpretation process. Given a definition of context, they explain the role of the granularity level of processing and the role of the abstraction level of application in modeling context. This makes it possible to have a representation under different viewpoints on the one hand, and to gather all contextual information in one place in the other hand. They also propose a definition of the contextual information of a process as the information verifying that its value remains constant during processing, and its value changes when the process is used for another application.

Ress D.A. and Young R.E. [29] use, as Turner, fuzzy logic in a constraint satisfaction system called FuzCon. The system work in a distributive environment such that large problems can be broken down into smaller constraint networks for easier processing. They identify contexts that exist within the constraint satisfaction system. The fuzzy constraint satisfaction system utilizes value propagation on constraints by formal logic and theorem proving. Context-based reasoning is identified both within and among constraint networks. The authors then point out three mappings of the context-based reasoning 'ist' operator to fuzzy constraints and by showing an example of designing a printed wiring board.

4.5 Discussion

A definition can be easily extend out of formal logic by the following claim:

"Context is what constrains a problem solving without intervening in it explicitly."

The claim is let here vague because we think that before to refine the definition, we need to position context at the level of the knowledge and its representation, at the level of the reasoning mechanism, or at the level of the human-machine interaction. We already point out that there is a different model of context at each level. Moreover, all these types of contexts are interdependent. For example, the way in which a user defines its request (concerning the interaction context) depends on the conceptual schema of the interrogated database (context at the level of the knowledge representation. In his book "Lector in Fabula", Umberto Eco [1985] discusses how the writer needs a model of a reader (to define the reading context) and how the writer may play to lead the reader in a cul-de-sac. This again illustrates the importance to well define context, and the context in which context is defined.

Contexts define when the knowledge should be considered. They permit to structure knowledge bases in tractable units, often organized in a hierarchy. A context contains: (i) sets of concepts (also called schemas, frames, or structures) that describe the basic terms used to encode knowledge in the ontology, and (ii) a set of constraints that restrict the manner in which instances of these concepts may be created and combined. Context-encapsulated knowledge appears as a chunk of reasoning. This is similar to claim that acquiring knowledge with its context of use, leads to organize knowledge representation into episodes [34]. Thus, contexts simplify the construction of the knowledge base by imposing requirements on the representation language. A challenge here is how knowledge in its context of use may be examined in other contexts (decontextualization of the knowledge).

The context is considered as something that is stored in long-term memory, and recalled as a whole, as a viable unit of task strategy appropriate to some stage of some task. A contextual system must have two types of memory: a long-term memory (a primary database and a base of contexts) and a short-term memory (intracontext knowledge processing and intercontext knowledge processing). The managing of these two types of memory may be organized with an algebra of contexts to involve contraction, extension, immersion, coupling and intersection of contexts [18]. A context may also be generated dynamically and, according to McCarthy, created from old contexts. The difficulty here is to determine if one needs to store all past contexts or, as proposed by Turner [32], have a set of "elementary" contexts that may be combine to constitute complex contexts to adequately represent a particular situation.

A solution for ensuring a correct transfer of information from one context to another is the context manager. A context manager makes compatible the interpretations (or reasonings) in the export and import contexts. It is supposed to: retain as much of the knowledge generated as possible; provide easy access to and a good explanation of this knowledge; make the best use of the knowledge already held in the dynamic knowledge base to enable it to generate new knowledge without performing redundant inference; and help the user to compare different, sometimes conflicting solutions. For example, a good context manager would make compatible users' requests and the conceptual schema of a database. The double action of a context manager on knowledge at a given step of a problem solving is: (i) to select the knowledge pieces for the focus of attention, and (ii) to keep in stand-by other knowledge pieces. However, a context manager acts at the level of the presentation of the knowledge than its representation (or its modelling).

The most interesting conclusions of these events are:

(1) Context is something surrounding an item and giving meaning to this item. It cannot be considered out of its use (one cannot speak about context apart from its context). Giving meaning to an item, context acts then more on the relationships between items than on items themselves.

(2) There are different types of context with respect to what we consider (knowledge, reasoning, interaction) and in which domain we are. All these contexts are interdependent, e.g. the interaction context is constrained by the knowledge context through, say, the model chosen to represent knowledge.

(3) There are different representations of the context depending if context is considered either as knowledge or as a process of contextualization. Context as knowledge implies that we must distinguish between contextualized knowledge (the knowledge effectively used at a given time) and contextual knowledge (the knowledge constraining the contextualized knowledge). Considering context as a process--a viewpoint close to the previous one--implies a distinction between knowledge, information and data. Data become information through the contextualization process on the basis of the available knowledge at the time of the observation.

(4) The lack of context representation in AI is responsible for the failures of knowledge-based systems, knowledge acquisition, machine learning, and explanation generation. Making context explicit will permit to develop powerful systems in complex tasks where the user plays a crucial role, generally having to take the final decision. However, one already speaks of contextual explanations, context-sensitive machine learning and of incremental knowledge acquisition for intelligent assistant systems.

We hope that this conclusion is only temporary and that other events focussing on context will develop the results obtained at this first international and interdisciplinary conference on context. The situation is different at the human-machine interaction level where coexist different contexts: the user's context, the context of the task at hand, the system context, and the context of the interaction.

The discussion however stays still open. Some of the questions that must be addressed are: Does part of the context belong to the knowledge base or a particular context base? What are the relationships between context and meta-knowledge? Knowledge representation? Time? What are the relationships between context, tactical decision and strategical decision? What are the relationships between contextualization process and control knowledge?

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