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Context-based Modeling of Operators' Practices by Contextual Graphs

Patrick Brézillon

LIP6, University Paris 6, Case 169, 8 rue du Capitaine Scott, 75015 Paris Cedex 05, France.

Patrick.Brezillon@lip6.fr – http://www-poleia.lip6.fr/~brezil/

Abstract. This paper presents a modeling of context for representing knowledge and reasoning, and more precisely procedures established by a company and the number of practices developed by operators for contextualizing procedures in their everyday context. We present how the three types of context proposed (external and contextual knowledge, and the proceduralized context are considered in the context-based formalism called contextual graphs. Several examples illustrate the use of this formalism.

Keywords. context, contextual graphs, procedures and practices, problem solving in real-world situations.

INTRODUCTION

The design of an artifact (a product or a building) involves the perception of its structure evolution during the design process, and the translation of each design state into the generation of new ideas. As captured by participants, the artifact attributes and their interrelations allow an organization of the design tasks based on the design state and the participants' role. This depends on the context in which the design evolves: each person builds his own interpretation context of the artifact design, linking his specialized universe with the collective goal of the team in which the person is. Note that the artifact itself influences strongly the context in which participants identify and relate the tasks to be accomplished (Bucciarelli, 1988).

In the SisPro environment (Borges *et al.*, 1999; Naveiro et al., 2002) to aid a design team in a design project, a set of functions enable synchronous and asynchronous communication and interaction among participants (see Figure 1). The environment includes two virtual workplaces: a virtual workspace attached to each specialist that defines their individual contexts and permits the communication among all professionals that are on-line; and, a virtual workspace for each project and common to all participants in the project that defines the team context and allows controlled communication among a project team and provides a place for negotiation among participants.

This real-world situation shows that in a collaborative work different types of context (e.g. privates contexts of the participants and the global context of the collaborative work) and their interaction must be considered explicitly. A similar situation in psychology is described in (Humphreys and Brézillon, 2002) about groups of youngsters in Peru.

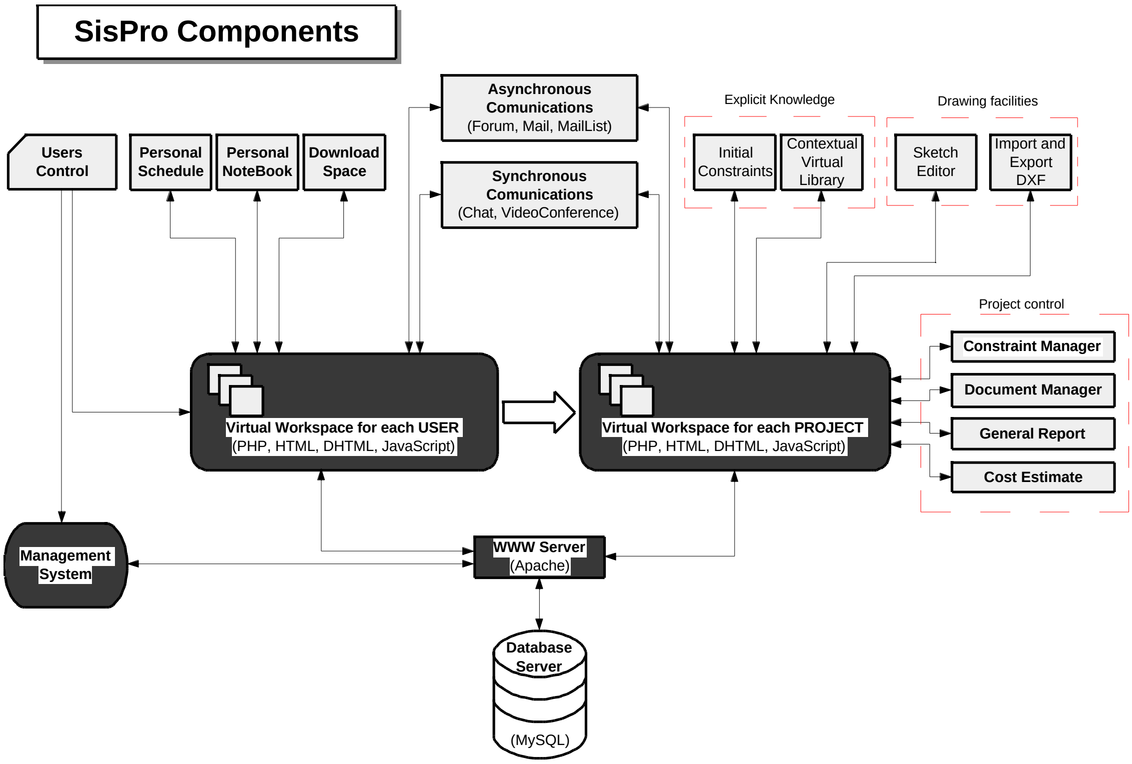

Figure 1: SisPro architecture (Borges et al., 1999)

One speaks about context only with reference to something: the context of an object, the context of interaction, the context of a problem solving, etc. However, only the context of interaction between agents seems of interest because it is in this context that other contexts are referenced or evolve. There are two families in the community interested by the context notion, the "tangible computing" and the "social computing" (Dourish, 2001). The interest of social computing is the development of context-based representation of knowledge and reasoning (e.g. see the example of the contextual graphs in Brézillon et al., 2001). This approach is essentially user-centered and deals with the dynamics of the context. Tangible computing is more concerned by the technical aspects of context that are immediately useable, particularly through an exploitation of data. The focus is mainly on mobile computing (context-aware applications, smart devices, ubiquitous computing, communicating objects, etc.) in domains as different as tourism and e-maintenance. Context in tangible computing is often limited to location and time, and the informations on the user are often ignored or very limited. This is a type of device-oriented approach and context is supposed to evolve only through occurrences of events. Clearly, there is a need to consider jointly these two approaches.

Hereafter, we present first procedures and practices. In the following section, we discuss our view on context with the three types of context, the contextual graphs, the building of the proceduralized context and the dynamics of the context. The section after presents a discussion before the conclusion.

PROCEDURES AND PRACTICES

At RATP (the subway company in Paris, France, see Pasquier, 2002), most of the incidents have been well-known for a long time (object on the track, lack of power supply, suicide, etc.). Thus, the company has established procedures for incident solving on the basis of their experience. However, each operator develops his own practice to solve an incident, and one observes almost as many practices as operators for a given procedure. Indeed, each operator relies heavily on the current context to tailor the procedure in order to take into account the current proceduralized context, which is particular and specific.

Operators prefer to plan again their action in real time rather than to rely on these procedures based on company's experience, this is due to two main reasons. Firstly, the selected procedure is not always perfectly adapted to the situation at hand and can lead to improper actions or sub-optimal incident resolution strategies. Secondly, if the operator relies on a procedure, he can miss some important facts and notice them too late to adequately solve the incident. Operators prefer generally to plan again their action continuously according to the situation. Procedures are then used as frames to construct a genuine strategy tailored to the specificity of a given situation. Such practices are based on operational knowledge and are shared by operators. This observation can be made in different domains.

Degani and Wiener (1997) distinguish procedures, practices and techniques. Procedures are specified beforehand by developers to save time during critical situations. Practices encompass what the users do with procedures. Ideally, procedures and practices should be the same, but the users either conform to procedure or deviate from it, even if the procedure is mandatory. Techniques are defined as personal methods for carrying out specific tasks without violating procedural constraints.

Bouaud et al. (1999) describe in medicine a type of operationalization of the knowledge from procedures to practices when a physician can make different therapeutical choices for a diagnosis according to the instantiation of the clinical context built from his perception of his understanding of the patient. Strauss et al. (1985) give the example of the unravelling plan for an osteoarthritis patient that might state that an X-ray image of the hip is necessary. But when applying the plan to Mr. Jones, who doesn’t have any problems with his hips, this part of the plan may be skipped – and other examinations, like a blood test, might be added to Mr. Jones’ unravelling plan. Thus, for the last authors, a protocol in medicine is a standard operating procedure (Strauss et al., 1985).

This discussion points out that if it is relatively easy to model procedures, the modeling of the corresponding practices is not an easy task because they are as many practices as contexts of occurrence. However, for complex incident solving, it is not possible to establish a global procedure, but only a set of sub-procedures for solving parts of the complex incidents. Moreover, procedures cannot catch the high interaction between the solving of the incident itself and the number of related tasks that are generated by the complex incident. As a consequence, there are as many strategies for solving an incident as operators: Cases that are similar in one context may be totally dissimilar in others as already quoted by Tversky (1977).

THREE TYPES OF CONTEXT

Recently, we proposed to understand and model the role of context in reasoning representation (Pomerol and Brézillon, 2001). Starting from these observations, we defined **contextual knowledge** as the part of the context that is relevant in a given situation for a given operator. This may be seen as the subset of the context in which the operator can find every chunk of knowledge for reasoning about or interpreting and explaining the situation. The complementary part in the context is called **external context**.

The **proceduralized context** is defined as the proceduralized part of the contextual knowledge, which is considered explicitly, with causal and consequential links, at a given step of the problem solving (Brézillon and Pomerol, 1999). This notion is relative to each operator, to the current situation and to the moment at which the operator is working. The proceduralized status of a chunk of context is not permanent since a contextual piece of knowledge is proceduralized when the operator focuses on it and goes back to its initial status of back-stage contextual knowledge when it is no longer mobilized in the reasoning.

An important issue is the passage from contextual knowledge to the proceduralized context. This proceduralization depends on the focus on a task. Thus, this is task-oriented just as know how; it is often triggered by an event or primed by the recognition of a pattern. Another aspect of proceduralization is that the persons transform contextual knowledge into some functional knowledge or causal and consequential reasoning in order to anticipate the result of their own action. This proceduralization obeys to the necessity of having a consistent explicative framework to anticipate the results of a decision or an action. This consistency is obtained by reasoning about causes and consequences in a given situation. We can thus separate the reasoning between diagnosing the real context and anticipating the follow up. The second step needs a conscious reasoning about causes and consequences.

We have developed our ideas in a contextual-graph representation of knowledge and reasoning in the framework of the SART application (see at http://www.lip6.fr/SART). However, the application of contextual graphs is not limited to the SART application. We present now how the context-based formalism called contextual-graphs can be used in any situation in which operators developed practices from the procedures imposed by the company.

Presentation of the contextual graphs

A contextual graph is an acyclic graph with a single source, a single sink, and a serie-parallel organization of nodes connected by oriented arcs. Figure 2 presents a pedagogical example. The different types of node are the actions (square boxes in Figure 2), the contextual and recombination nodes (large white and small black circles), the sub-graphs and the parallel grouping (the two last items are not represented in Figure 2). The algorithm, which is described by the contextual graph formalism, always ends. A sub-graph allows the modeling of operators' activities, and thus contextual graphs give a representation of the reasoning directly understandable by operators. A path is an ordered sequence of elements (contextual and recombination nodes and actions) of the contextual graph from the source to the sink. Each path represents, by its sequence of actions, a practice.

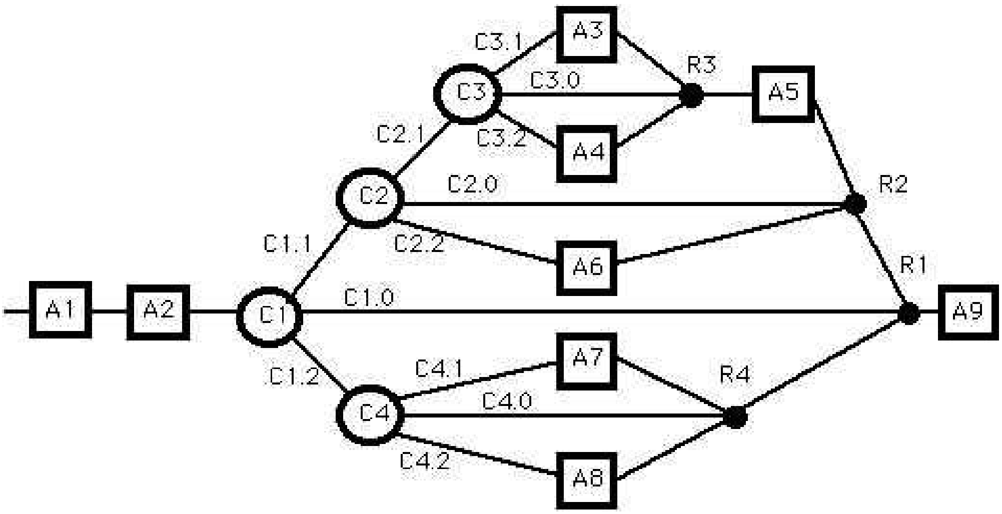

Figure 2: A pedagogical example of contextual graph

The context of the contextual graph presented in Figure 1 is given by the elements {C1, C2, C3, C4}. The context of an action (e.g. A3 at the top of Figure 2) is composed of two parts: the contextual elements used on the path from the input and the other elements. On the path, some of the contextual elements has a value that intervenes in the practice (C1 with the value C1.1, C2 with the value C2.1 and C3 with the value C3.1) and other not (the value of C4 does not matter because being out of the path its instantiation is not considered). The first ones intervene in an ordered way and are called the proceduralized context. The second one is the set of elements called the contextual knowledge.

Thus, the context of the action 3 is defined by:

- Its proceduralized context: {C1 with the value C1.2, C2 with the value C2.1, C3 with the value C3.1}, supposing that the actions A1 and A2 are realized.

- The contextual knowledge: {C4}

Note that the proceduralized context is an ordered sequence of contextual-knowledge pieces with their values: { (C1, C1.1), (C2, C2.1), (C3, C3.1) }. In the context of the action A3 there is also the knowledge that the actions A1 and A2 have been executed.

The main interest of contextual graphs relies on the possibility to introduce easily new practices in contextual graphs. A new practice generally corresponds at a known practice with few changes introduced by contextual nodes. Thus, a contextual graph based system either knows a practice used by an operator or acquires it when need. It is no more necessary to develop an exhaustive representation of an incident-solving prior its use. Figure 3 give the classical example in the literature of the coffee preparation (e.g. see UML manual). In this figure, vertical bold lines represent parallel grouping expressing the fact that some actions (e.g. "Take coffee" and "Take filter") can be executed in parallel. The contextual-graph formalism allows the representation of a number of variants ("To be in hurry", "Choice of the type of water", "Moment of the day", etc.). This example shows also the limits of the representation of some contextual knowledge at the level of the temporal branching. The example shows that in some situations, that is, the choice of the ordering of the actions "Take reservoir", "Take filter", "Take coffee" depends on a so dense net of contextual nodes for finally six possibilities that it is better to impose only a global constraint on the execution of the three actions before to continue the process.

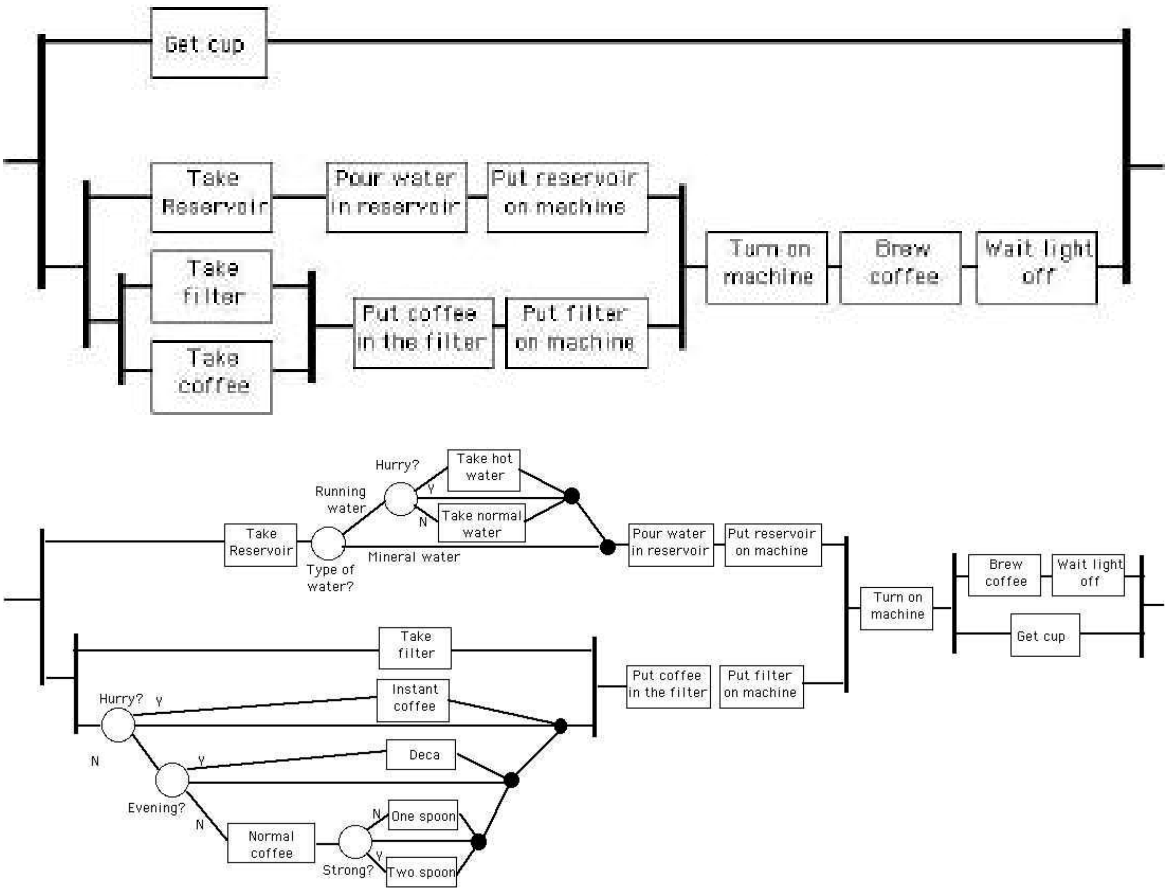

Figure 3: The example of coffee preparation in contextual graph (a) as found in the literature, and (b) after assimilation of some "practices"

Building of the proceduralized context

The proceduralized context represents some functional knowledge or causal and consequential reasoning. This description matches the situations experienced by engineers or architects when they have to look ahead to the consequence of their design decisions.

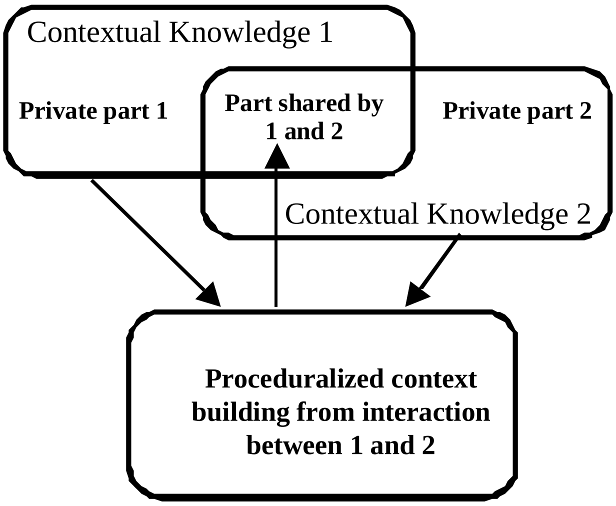

Figure 4: The process of building a shared conception of an artifact

The construction of the proceduralized context from contextual knowledge is often a process of communication in a community of practice, even if members of this community come from different domains. Figure 4 represents how the proceduralized context is built from contextual knowledge during the interaction between two persons. The interaction context contains pieces of the contextual knowledge that are introduced by a person for the building of the proceduralized context in the focus of attention of the persons. These pieces of knowledge in the interaction context are extracted from the contextual knowledge of each person. They are jointly organized, structured and proceduralized by the two persons, and result in a shared chunk of knowledge. Generally, on the request of the other, a person may add some pieces of knowledge related to his previous utterance as a kind of explanation. This progressive building of the proceduralized context is particularly important during a phase of negotiation because any element that is added must be accepted by both participants in the interaction, but also the way in which the new piece of contextual knowledge is linked to pieces of contextual knowledge already in the interaction context. If the final chunk of knowledge under construction is accepted by the two persons, the knowledge pieces in the interaction context are integrated into a mutually acceptable knowledge structure—the proceduralized context, and then moved to their shared contextual knowledge when it gets off from the focus of the attention.

Thus, the proceduralized context contains all the pieces of knowledge that have been discussed, accepted and assembled by all the participants (at least with compatible assembling). This is a kind of learning by negotiating. This new chunk of contextual knowledge (the proceduralized context at the previous step) may be recalled later as a whole, as any piece of contextual knowledge, to be integrated in a new proceduralized context. Thus, the more a person is experimented, the more the person possesses available structured knowledge. This explains why experts' knowledge is more structured than novices' knowledge.

The dynamic dimension of context

Consider again the example of Figure 2. The context of the action A3 in the previous example is described in a fixed and static way. Once the action A3 is executed, the value C3.1 of C3 does not matter anymore and the contextual element leaves at R3 the proceduralized context to go back to contextual knowledge. Thus, the context of the action A5, which follows the execution of the action A3, is described by:
- the proceduralized context: {C1 with the value C1.2, and C2 with the value C2.1}, and
- the contextual knowledge: {C3, C4}.
The context of the action A5 is also described in a fixed and static way.

Thus, each action is associated with a fixed and static context. The dynamic in the context appears at the practice level. The contextual knowledge and the proceduralized context evolve during the application of a practice (along a path). For example, consider the practice: {A1, A2, A3, A5, A9}. Its context presents the following dynamic along the practice application (each line of the Table represents a step in the application of the practice, a step corresponding to a change in the context):

L	Context of	Contextual Knowledge	Proceduralized context
1	A1-A2	{C1, C2, C3, C4}	{Ø}
2		{C2, C3, C4}	{C1.1}
3		{C3, C4}	{C1.1, C2.1}
4	A3	{C4}	{ C1.1, C2.1, C3.1}
5	A5	{C3, C4}	{C1.1, C2.1}
6		{C2, C3, C4}	{C1.1}
7	A9	{C1, C2, C3, C4}	{Ø}

The movement inside the context (and its dynamic from an outside viewpoint) arises from a contextual element entering the proceduralized context by its instantiation, or, conversely, the withdrawal of the instantiation of a contextual element (becoming again a piece of contextual knowledge). As proceduralized context is an ordered sequence of contextual elements considered through their instantiations and by the type of the contextual graphs (one input, one output), the movement from the proceduralized context to the contextual knowledge follows the rule "last in, first out". The movement itself is an element of the context. Thus, two contexts having the same contextual knowledge and proceduralized context (as at line 3 and 5 of the Table above) are different.

CONCLUSION

The roles played by the context are different if the object is mobile or not. The reason is that the environment itself has a dynamic particularly important for a mobile object. For example, changes in the environment can transform an optimal solution in an inadequate solution in another context (Brézillon, 1999). Moreover, two concepts can be close in a context and distant in another one. A mobile object must be able to revise all its beliefs at a given moment, even during the course of a plan execution. This supposes that the object can follow user's actions and watch for an eventual derive of the observed behavior with respect to a predicted behavior (e.g. see (Brézillon et al., 2000) on case-based intelligent assistant systems). The objective is to insure that the local user's needs respect global constraints at any time.

Up to date, the dynamic of the environment is taken into account through the evolution of physical factors as user's location, time of the request. However, this dynamic should take into account also knowledge, not only data, on the environment and the user.

A system using contextual knowledge can develop a user's model increasingly elaborated along user-system interaction. Note that we do not speak of a model drawn from a library but an online modeling of the user as the system can view him, i.e. through their interaction. Thus, the system can provide relevant answers to user's questions, and even helping first the user in the formulation of his questions. The experience acquired by the system with a user accomplishing a task then can be reused for helping the same user in other tasks.

A system can also reuse the experience acquired with a user for helping other users with the same task. This is realized directly with either a stand-alone system or by interaction among agents. In the latter situation, each agent helps a user (e.g. see the works of Maes at MIT for the last approach), the agents exchanging their experience with their user to support other agents.

A system can support a collaborative work between humans by intervening in all the phases of the collaboration (cooperation, negotiation, etc.). This situation is increasingly important when manufactured objects are more and more complex and require the collaboration of different specialists (think to the design of a spacecraft). The system can then take in charge the adjustment of individual contexts of the users in order to make compatible their interpretation on a given event (Karsenty and Brézillon, 1995). For example, a TV, as a communicating object, would have to make compatible the interests (eventually diverging interests) of the father, the mother and the children (say, a boy and a girl).

The granularity of the context can be compared to a distance measure from a contextual element to the focus of attention. More the contextual element is close of the focus, more context is detailed. For example, for sending a letter, you need to know with details what is the way from where you are to the nearest letterbox, when you only need to know that the location of Scotland (from Paris) is North.

Practically, context granularity is restricted now to the distinction between a local context and a global context. Van Dijk (1998) gives a good example in the analysis of political discourses. In computer-aware applications, the system Fisheye do a similar operation (Pook, 2000). However, this approach is not new: Conceptual graphs already proposes mechanisms of aggregation and expansion (Sowa, 2000)). Nevertheless, context must be represented in machine in an efficient way for modeling knowledge and reasoning, from the programming point of view as well as the viewpoint of its effective use.

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