Some Characteristics of Context

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Abstract. Drawn from the lessons learned in an application for the subway company in Paris, we pointed out that operators used practices instead of the procedures developed by the company, practices appearing like contextualization of the procedures taking into account specificity of the task at hand and the current situation. This leads us to propose, first, a working definition of context at a theoretical level, and, second, its implementation in a software called Contextual Graphs. In this paper, we present the results of the complete loop, showing how the theoretical view is intertwined with the implemented one. Several results of the literature are discussed too. Beyond this internal coherence of our view on context, we consider knowledge acquisition, learning and explanation generation in our framework. Indeed, these tasks must be considered as integrated naturally with the task at hand of the user.

1 Introduction

Contextual graphs are used in several domains such as medicine, ergonomics, psychology, army, information retrieval, computer security, road safety, etc. [1]. The common factor in all these domains is that the reasoning is described by procedures established by the enterprise. These procedures are tailored by actors that take into account the context in which they have to deal with the focus. Thus actors create practices as contextualizations of procedures. A practical reasoning is not a logical and theoretical reasoning for which the action leads to a conclusion. In a practical reasoning, the conclusion cannot be detached from the premises, i.e. take a meaning out of these premises.

Thus, each actor develops his own practice to address a focus in a given context, and one observes almost as many practices as actors for a given procedure because each actor tailors the procedure in order to take into account the current context, which is particular and specific.

If it is relatively easy to model procedures, the modeling of practices is not an easy task because they are as many practices as contexts of occurrence of a given focus. Moreover, procedures cannot catch the high interaction between the task at hand and the related tasks that are generated by the task itself.

Hereafter, the paper is organized in the following way. Section 2 presents the lessons learned on context up to now, from our working definition to an example of the contextual graphs we have implemented. Section 3 discusses how context appears in a

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contextual-graph representation through some elements such as its related focus, the representation as contextual elements, the enrichment of a contextual graph, and the building of the proceduralized context in contextual graphs. Section 4 concludes by giving a global coherent picture of context and points out, as a new axe of research how an item of contextual graphs could be the result of a mixing of levels of representation.

2 Lessons Learned on Context

2.1 Our Working Definition

For a given focus of an actor, Brézillon and Pomerol [2] consider context as the sum of three types of knowledge. First, there is the part of the context that is relevant at this step of the decision making, and the part that is not relevant. The latter part is called **external knowledge**. External knowledge appears in different sources, such as the knowledge known by the actor but let implicit with respect to the current focus, the knowledge unknown to the actor (out of his competence), contextual knowledge of other actors in a team, etc.

The former part is called **contextual knowledge**, and obviously depends on the actor and on the focus at hand. However, the frontier between external and contextual knowledge is porous and evolves with the progress of the focus.

For addressing the current focus, the actor selects a sub-set of the contextual knowledge, assembles, organizes and structures it for addressing the current focus. We call the result the **proceduralized context**. When an element of the contextual knowledge moves in the proceduralized context, this means that we consider explicitly its current instantiation and its particular position with respect to other contextual elements already in the proceduralized context.

Sometimes, the building of a proceduralized context fails to account for the current focus of the actor. Then, the actor must provide new (external) knowledge to allow the system to learn a new practice. There are simultaneously an incremental acquisition of new contextual elements and the learning of a new practice. With this joint acquisition and learning tasks, the system is fed with the specific context of occurrence.

This triple aspect—context growth by integration of external knowledge in the PC building, by integration of a new "chunk of knowledge" in the contextual knowledge, and context change by the movement between the body of contextual knowledge and proceduralized contexts—illustrates the dynamic dimension of context [1]. Without an explicit representation of this dynamic dimension, it is not possible to catch entirely context in an application.

Once the current focus is satisfied, the proceduralized context becomes a piece of contextual knowledge. This "chunk of knowledge" [7] will exist with its building blocks (the contextual-knowledge items retained initially and the way in which they have been assembled).

2.2 Contextual-Graph Representation

A contextual graph is a context-based representation of all the practices that have been used in a problem solving. Contextual graphs are oriented, acyclic, with exactly one input and one output, and a general structure of spindle. A path (from the input to the output of the graph) represents a practice (or a procedure), a type of execution of the task with the application of selected methods. A contextual graph is an acyclic graph because user's tasks are generally in ordered sequences. For example, the activity "Make the train empty of travelers" is always considered at the beginning of an incident solving on a subway line, never at the end of the incident solving.

Elements of a contextual graph are: actions, contextual elements, sub-graphs, activities and parallel action groupings.

- An **action** is the building block of contextual graphs. It must be understood in the spirit of task.
- A **contextual element** is a couple of nodes, a contextual node has one input and N outputs (branches) corresponding to N known instantiations of the contextual element, and a recombination node [N, 1] from which the instantiation does not matter anymore. The contextual element is instantiated only between the contextual node and the recombination node.
- A **sub-graph** is itself a contextual graph. It is mainly used for obtaining different displays of the contextual graph on the graphical interface by some mechanisms of aggregation and expansion like in Sowa's conceptual graphs [9].
- An **activity** is a particular sub-graph (and thus also a contextual graph by itself) that is identified by actors because appearing in several contextual graphs. This recurring sub-structure is generally considered as a complex action.
- A **parallel action grouping** expresses the fact (and reduce the complexity of the representation) that several groups of actions must be accomplished in parallel or in any order before to continue the practice application. The parallel action grouping is a kind of complex representation of contexts. This item expresses a problem of representation of items at a too low level of granularity.

Indeed, we distinguish between these elements, and their instances in contextual graphs. For example, the action A5 in Figure 1 appears several times on different branches (and thus different contexts).

Right now, there is a software for visualizing contextual graphs and incrementally acquiring new practices. There are already a number of functions (zoom, handling of parts of a graph, change of language, etc.) for handling contextual graphs and the current development concerns the introduction of explanations. The use of this software in a number of applications shows that if the software itself cannot be separated from its interface (because of the incremental acquisition capability), the software is really independent of the applications already developed.

2.3 An Example

Figure 1 presents an Activity in the contextual graph given in [2]. This contextual graph represents the different practices that can be used during the information exploitation on a link target during a Web search. Square boxes represent actions,

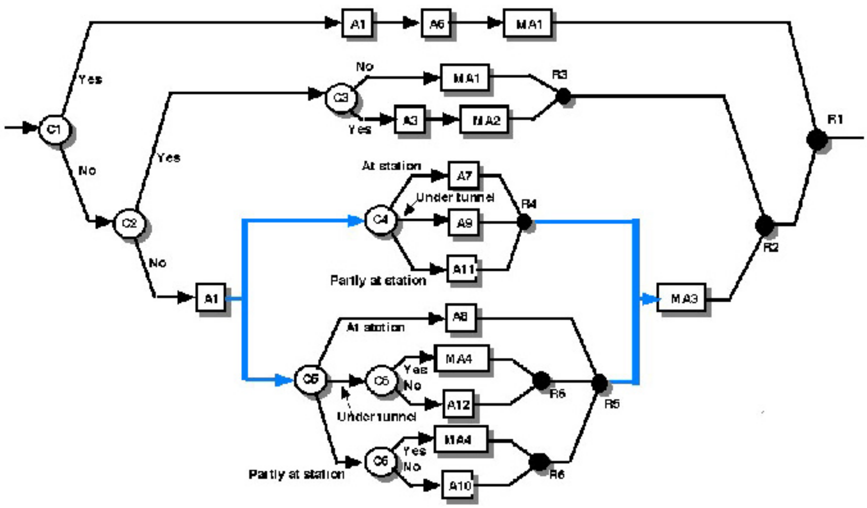

Fig. 1. Evacuation of a damaged train

Table 1. Evacuation of a damaged train [2]: Meaning of the items appearing in Figure 1 with C for contextual elements and A for actions

Actions	
1	Residual traffic regulation
2	Damaged train continues with travelers
3	Damaged train continues with travelers until a steep incline
4	Damaged train restarts without travelers
5	Stable damaged train at end station
6	Repair damage
7	Exit of travelers out of the damaged train
8	Exit of travelers out of next train
9	Exit of travelers out of damaged train via available cars
10	Exit of travelers out of next train via available cars
11	Exit of the travelers out of damaged train via track
12	Exit of travelers out of next train via track
13	Next train joins damaged train
14	Link both trains
15	Convoy return to end station
16	Disassemble convoy
17	Next train goes to next station

Contextual elements	
C1	Immediate repair possible?
C2	Enough motor coaches available?
C3	Is there a steep incline between the damaged train and end station
C4	Position of the damaged train?
C5	Position of the following train?
C6	Presence of a station between the two trains?

Macro-actions	
MA1	Damaged train continues service (Actions A2 – A5)
MA2	Damaged train stops service (Actions A7 – A4 – A5)
MA3	Make a convoy with damaged train and next train (Actions 13, 14, 15, 5 and 16)
MA4	Empty next train at a station (Action A17 – A8)

circles represent contextual elements (large circles for contextual nodes and black circles for recombination nodes). A path (i.e. a practice) is followed from the left to the right and corresponds to the crossing of a series of elements.

3 Context in the Contextual-Graph Representation

3.1 Context and Its Related Focus

A contextual graph, like in Figure 1, contains only contextual elements (the contextual knowledge in Section 2). The external knowledge is not included in a contextual graph, but is a source for new elements in a contextual graph, and introduced by the actors when needed. This is why the infinite dimension of context [5] is not a problem in such a representation.

The proceduralized context appears when the focus is on an item of the contextual graph and/or the development of a practice. For any item (where is the current focus) on a practice, contextual elements from the source to this item are instantiated, if the recombination node has not been crossed equally. The proceduralized context corresponds to an ordered sequence of instantiated contextual elements.

If the focus concerns a given item of the practice, say action A6 in Figure 1, then one has a static context with two pieces of contextual knowledge (C9 and C11), and an ordered sequence of instantiated contextual elements corresponding to the proceduralized context (C8 with the value "Short", C12 with the value "Exploratory", C3 with the value "Yes", and C4 with the value "Yes").

If the focus concerns the practice itself, then by the play of the contextual elements entering the proceduralized context, say at C4 in Figure 1, or leaving it such as at R4, the context of the practice presents a dynamic. We will see in the following that there is another type of dynamics coming from the incremental acquisition of knowledge.

3.2 Representation of Context Like Contextual Elements

Contextual knowledge is represented by contextual elements. As shown in Table 1, contextual elements constitute a heterogeneous population of elements (coming from different domains), and there is no real hierarchy, at least in the semantic sense. The organization of the contextual elements is more oriented by the problem solving it self.

The branches between a contextual node and a recombination node are exclusive, each corresponding to a given instance of the contextual element. However, if a contextual element appears on a branch on another contextual element (say C4-R4 on the branch "Yes" of the contextual element 3), the contextual element must exist only on the branch of the other contextual element. Thus a contextual element is always defined (embedded) with respect to another contextual element, as already said by McCarthy [5]. We have been a step further with the onion metaphor [4, 6] by showing that contextual elements are organized by layers around actions.

By their position, contextual elements are more related to the relationships between the elements of reasoning (the actions) that on the elements themselves.

3.3 Enrichment of a Contextual Graph

When the system fails to represent the practice used by an actor (given as a sequence of actions such as A13-A6-A14 for the upper path), the system presents the actor the practice the nearest of the actor's practice, exhibits the differing part between the practices, and ask for an explanation. For example, in Figure 2, there was A13 followed, say, by action A7 according to the contextual element C3 (implicitly the type of search was supposed to be exploratory).

However, an actor may decide to look for the phone number of a colleague on the Web and gives very precise keywords and has his answer in the first link provided by the search engine. The actor then explains the system that the contextual element C12 "types of search?" must be introduced because the treatment is different from the previous one, i.e. an exploratory search. A new practice is generally introduce in a contextual graph as a variant of an existing practice differing from the previous one by few element (generally a contextual element and an action or an activity). Thus, a system using a contextual-graph presentation incrementally acquires new knowledge and, simultaneously, learns a new practice when it fails to account for user's practice.

By accumulation of all the practices used for a problem solving, a contextual graph could be assimilated to a kind of ”micro-corporate memory” for the problem solving represented by this contextual graph. A contextual graph is living, it can be used for monitoring, diagnosis, simulation, explanation, etc. Although, we have not work in this direction, a base of contextual graphs can cover all a domain and thus bring a solution to knowledge management.

3.4 Context Structures

If we represent contextual elements of Figure 1 by ovals alone, without the actions and paths, we obtain Figure 2. There are some observations to make.

First, a contextual element is always embedded in another contextual element (or several ones). Contextual elements never intersect. Thus, a contextual element, as a focus, is itself in a context. In a contextual graph, the dimension of context is finite, limited by the number of practices learnt by the system.

About the infinite dimension of context pointed out by McCarthy [5], we observe that the dimension of context is infinite in two senses: any contextual element may contain another contextual element (e.g. C4 contains C11) and is contained in another contextual element (e.g. C4 is contained in C3). This is recursive and only limited by the record of experience. A contextual graph representing a unique problem solving, the number of methods that can be used for problem solving is limited. However, we have not yet explored the possibility of the solving of highly complex problems.

Second, the development of a practice is a series of input/output of contextual elements according to the law "last in, first out." There is some similarity with the work of Giunchiglia's team (e.g. see [8]). For example, in C3 we go first in C4 and them in C9 (without excluding the possibility to avoir C4 or C9). In contextual graph, on the one hand, contextual elements are embedded, but discrete as in Giunchiglia's work.

On the other hand, the "bridging rules" in the Italian work correspond to instantiation of the context at the upper level (e.g., the instantiation of C3). This is a new path to explore to developing contextual graphs as a formalism of representation of the knowledge and the reasoning.

Third, contextual elements are knowledge pieces in various domains and just assembled by an individual (e.g. see definitions of C3, C4, C9 in Table 1). Thus, there is a refinement of practices by taking increasingly into account contextual elements. The organization of contextual elements in a contextual graph is more related to the growth of the contextual graph from the initial procedure than to an intrinsic property (like an ontology on contextual elements). This is very similar of our experimental finding five years ago in the application for the subway company in Paris [4] such as represented in Figure 3.

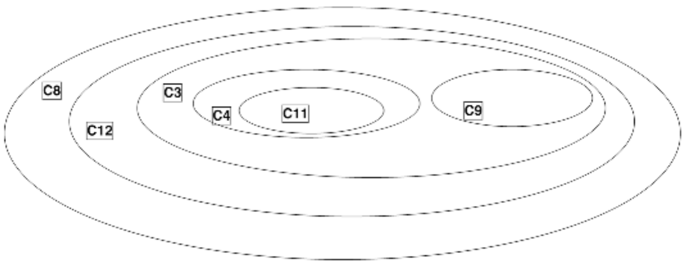

Fig. 2. Organization of the contextual elements in Figure 1

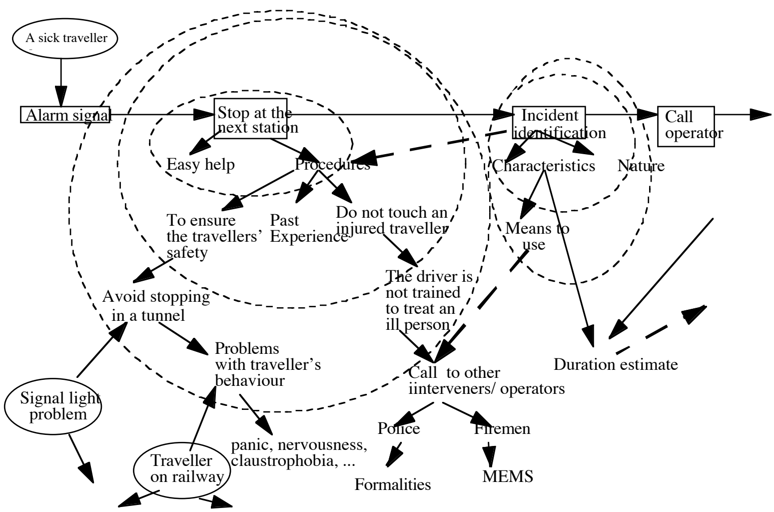

Fig. 3. Context organization in the SART application (Brézillon et al., 2000)

4 Conclusion

Contextual graphs offer a uniform representation of elements of reasoning and contextual elements at the same level. Context in our formalism intervenes more at the levels of the links between actions than actions themselves. Contextual elements being organized in contextual graphs in the spirit of "nest of dolls", we have not a hierarchy of context because a given contextual element is itself contextualized and can appear encompassed in different other contextual elements. Rather, a contextual element is a factor of knowledge activation.

We show that contextual issues cannot be addressed in a static framework only and that eliciting and sharing contextual knowledge in a dynamic way is a key process in addressing and understanding context problems.

The introduction of the item "Parallel Action Grouping" (PAG) simplifies the representation of contextual graphs. However, if an activity is assimilated to a complex action, a PAG is more than a complex contextual element. An activity sums up a complexity at the same level of representation. A parallel action grouping generally represents (as a simplification) a complex entanglement of contextual elements corresponding to a low level of description of the problem solving modeled in the contextual graph. In the popular example of the coffee preparation given in UML manuals, it is said that we must take the coffee and the filter in one order or the other (or in parallel). However, according to the type of coffee machine (e.g. we must put it apart to fill the reservoir with water), the piece of the coffee machine where must be put the filter can be independent of the coffee machine, mobile on the coffee machine or fixed into the coffee machine. Each situation would be considered independently, but all situations will conclude on a unique action: "Put the coffee in the filter." Thus, instead of making complicated a contextual graph for representing its (natural) complexity, which is at a lower level of detail, we use parallel action groupings.

Information can be drawn from a contextual graph, such as the way in which it has been developed, which actors has developed a given part of the contextual graph. It is possible to have an evaluation of the distance between two practices (i.e. two paths in the contextual graphs). Contextual graphs are a formalism of representation allowing the description of decision making in which context influences the line of reasoning (e.g. choice of a method for accomplishing a task). This formalism has been already used in different domains such as medicine, incident management on a subway line, road sign interpretation by a driver, computer security, psychology, cognitive ergonomics, usual actions in a house (preparing hard-boiled eggs, change of an electric bulb, etc.). The extensions that will be given to this work concerns: (1) its introduction in an intelligent assistant system for providing suggestions to the actor, (2) the management of the database (operations on the items, regrouping contextual elements, etc.) in order to produce robust procedures; statistics on the development, use of a given path; and (3) the introduction of a module of explanation generation of different types and at different levels of details.

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