Is Context a Kind of Collective Tacit Knowledge?

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ABSTRACT
Many attempts have been made to capture the very nature of knowledge in different fields: philosophy, cognitive science, artificial intelligence, etc. There is now a renewal of the studies on context and several proposals to represent and implement the context in "intelligent" systems. Up to now, there were, as far as we know, few attempts to compare the two concepts of context and knowledge, while they obviously share some common aspects. In this paper, we review the main characteristics of both concepts and, while we note a large overlapping of the two concepts, we also emphasize their differences as regards decision making and action.

Keywords
Decision Support Systems, Intelligent Assistant Systems, Context, Knowledge types.

INTRODUCTION
On the one hand, many attempts have been made to capture the very nature of knowledge. These analyses come from different fields: philosophy, cognitive science, artificial intelligence, etc. On the other hand, there is now a renewal of the studies on context and several proposals to represent and implement the context in "intelligent" systems.

Up to now, there were, as far as we know, few attempts to compare the two concepts of context and knowledge, while they obviously share some common aspects. In this paper, we review the main characteristics of both concepts as they appear in the engineering field and, while we note a large overlapping of the two concepts, we also emphasize their differences as regards decision making and action.

In the following, we start by reviewing the most famous views and definitions of knowledge. After, we give some characteristics of knowledge that seems important as regards to context. Then, we introduce the notion of context with its main components. Finally, we stress the differences between knowledge and context.

KNOWLEDGE FOR COMPUTER SCIENTISTS
Researchers in computer science, mainly in artificial intelligence (AI) generally try to define knowledge by a process of progressive construction going back to data, which are the symbols perceived by a subject whether these data are already structured either by the perception device or by the machine which conveys them. From data emerges information which is data with a strong semantic content. Thus, information is structured data with a semantic content expressible by natural language. Information is generally framed by a subject but it is sharable and is immediately usable by human beings on the basis of their knowledge. It is sometimes argued that context is used both to transform data into information [37, 39] or/and to acquire knowledge [2].

The next transformation in the appropriation process is the passage from information to knowledge. This appropriation process relies on prior knowledge and is made consistent with the values and beliefs of a subject. For example, according to the previous more or less common views, Aamodt and Nygard [1] distinguish between data, information and knowledge. Furthermore, these authors propose to consider data as input in the interpretation process, *i.e.* in the initial step of decision making. In this scheme, the data are the stimuli which enter the interpreter according to the classical view of the Information Processing Systems [25]. Information is then data with a meaning visible or understandable, *i.e*. with a structure or which can be expressed in a language. This is the output from data interpretation as well as the input of the knowledge-based process of decision making. Knowledge is information incorporated in an agent's reasoning and made ready either for active use within a decision process or for action. It is the output of a learning process. Thus, the roles of knowledge are to: (1) transform data into information, (2) derive new information from existing ones, and (3) acquire new knowledge pieces. The interpretation process adds structure and expressiveness to data, transforming data into information. The second step corresponds to the transformation of information into knowledge. At this point, we cannot hide that knowledge must have also some validity. This is why knowledge is often defined as "justified true belief." This paves the way to new questions: what is justified and who justifies? In a word, does a person who know everything about astrology has some knowledge for an observer who does not believe into astral influence?

The main differences between information and knowledge results from the appropriation process and the re-thinking of information in an organized meaningful corpus with consequential and causal links. In other words, knowledge is the information that is integrated and understood in the mind of a given subject. One of the difficulties with this

definition is that knowledge is necessary to transform data into information and that knowledge is the result of the appropriation process (learning). It follows that knowledge is both a means and a result of this complex process: Knowledge must be managed as an object and a process [39]. Another difficult question is that some knowledge is also necessary to structure the unorganized stimuli emerging from the "primordial symbolic soup" and to shape rough stimuli into data. In artificial systems, the structuration introduced by the sensors results from the designer's intelligence. For animals as well as human beings, one can invoke a transcendental hand or evolution. This leads to the well known philosophical paradox stating that "knowing comes before recognizing" but, in this case, from where knowing comes? At least this last problem does not occurs in automatic pattern recognition because the knowledge is provided by the designer of the system.

Figure 1 sums up our view in a scheme that is far from being original since these ideas, at least the different layers, are more or less commonplace in the Artificial Intelligence community, although not always so clearly stated.

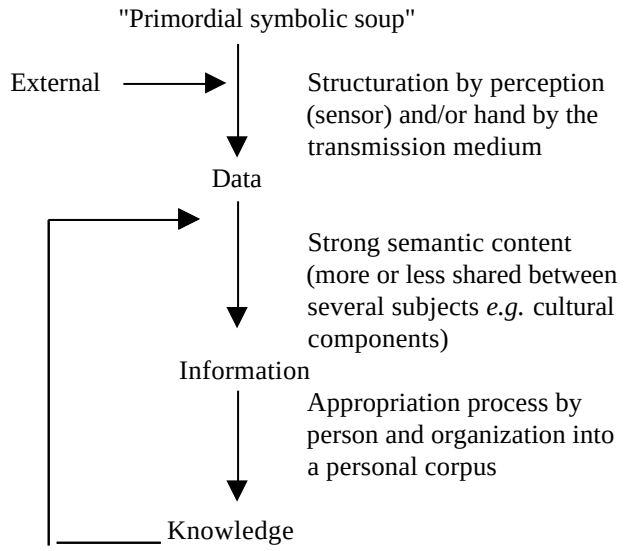

Figure 1: From the "primordial symbolic soup" to knowledge

These basic ideas about knowledge being recalled, let us now examine what are the main attributes and modes of knowledge.

KNOWLEDGE CHARACTERISTICS

One of the first distinction between the different forms of knowledge in an operational setting goes back to Ryle [32]. This concerns *know how* versus *know that*. The term *know how* refers to the knowledge that people use to operate or behave as opposed to *theoretical knowledge* which is related to the profound, ultimate and often hidden causes of the on-going phenomenon. Carr [8] defines *know how* as essentially different from theory while expressed by rules : "*Inter alia*, *knowing how* in the strong sense to play football is knowing the rules of the game, but a statement of the rules of the game is not a theoretical statement but a description of a set of rules of practice, and mastery of the rules brings with it an understanding of an activity rather than a theory. Statements of the rules of a game are essentially of relations between prescription…" In Carr's example we can guess that theoretical knowledge about football would explain the genesis of the rules and the ultimate origin and the social role of this particular game. This distinction between "theory" and "practice" is commonplace in many domains close to cognitive science. However, we will show that practice is more context dependent than theory.

In the AI field, the previous distinction is intertwined with the discussion about *deep* and *surface knowledge* (see *e.g.* [34]). It is commonly admitted in AI that *deep knowledge* refers to models and causal explanations that goes back to nature laws, whereas the *surface knowledge* is represented by practical rules that can be acquired from people performing efficiently a given task (human experts). Thus, we see that, on the one hand, the *deep knowledge* is very similar to *know that*. On the other hand, it is not so clear that *surface knowledge* is equivalent to *know how*.

The discussion *deep* vs. *surface* is contemporary to the distinction between *procedural and declarative knowledge* which was introduced early in artificial intelligence. Roughly speaking, *procedural knowledge* is knowledge which is expressed in expert systems by rules or, in organizational life, by procedures. *Declarative knowledge* refers to more descriptive knowledge represented by objects or agents in new programming languages. This distinction between rules and descriptive patterns like frames or objects is related to some psychological issues and the difference between rule-based behavior and more intuitive recognition-primed reactions has been early emphasized in AI.

The notion of "practicability" offers another possible way of analysis. This has been renewed by the study of "communities of practice" [6, 7]. This notion of *practical knowledge* is particularly relevant in learning because it has been observed for centuries that some knowledge needs *apprenticeship* (*i.e.* practice) to be learnt whereas some other does not necessitate such practice.

In few words, a French proverb states that it is by marshalling that you will become a marshal whereas, for example, you can learn about blood circulation and the role of the heart without dissection, because you trust your professor or a textbook. This discussion is not far from the previous one in the sense that *deep knowledge* is probably something which can be acquired without practice, but *surface knowledge* certainly cannot be assimilated without practice [10].

This last problem is recurrent in knowledge engineering, and the lack of contextual information about the task at

hand has been recognized as a weakness of rule-based systems [4]. In apprenticeship the contextual information is acquired by doing. Actually, mastery in a job may partly results from some rules which are given by masters but practice or *knowing how* cannot be reduced to rules, this is just the first reason why apprenticeship is necessary. The second reason is that learning is a social process as underlined by the literature on community of practice. However, learning *deep knowledge* is probably also a social process of another kind and it is not likely that isolated individuals can learn everything in books or on the web (see [7] for a discussion on this last point).

The question of the practical knowledge nature opens another discussion about *tacitness* versus *explicitness*. This discussion has been recently enlightened by Nonaka [26] who distinguishes *explicit* and *implicit knowledge* and the movements between them (see also [11, 13, 12]). *Explicit knowledge* is easily shared whereas *implicit knowledge* is highly personal. This last type of knowledge is the result of some internal processing [29]. In decision making, this is reminiscent to Klein's Recognition-Primed Decision [20]. The discussion about *tacit* versus *explicit knowledge* is not far from *knowing how* versus *knowing that* while it stresses the appropriation components. The *tacit knowledge* implicitly belongs to somebody whereas *explicit knowledge* can be shared and is generally public. We would also distinguish between *tacit knowledge* which can be explicited and non-explicitable *tacit knowledge*, even if this latter can be shared in a community of practice. This is the case of many handling skills in a lot of craft jobs.

The consciousness of *knowing that* was a point already made in [32] moreover consciousness implies that *knowing that* can be explained and shared with other thinking subjects, but neither necessarily reduced to rules nor explicited. The notions of *procedural and declarative knowledge* have been brought into contact with the implicit-explicit distinction by several authors. For instance, [16, 17] characterized implicit knowledge as a *procedural knowledge* whose accessibility for the other parts of the system is limited. *Accessibility* has also been emphasized as the central issue in the distinction between *procedural and declarative knowledge* in [19]. Squire [33] characterized the knowledge about the past that is typically impaired in amnesia as declarative memory (where declarative is largely considered as a terminological variant of explicit memory or *knowing that*) and contrasted this to non declarative memory (*i.e*. implicit *knowing how*) that includes procedural memory (habits, skills and conditioned reactions) but also memory of facts revealed by priming.

Between *tacit* and *explicit knowledge*, Nonaka describes four types of exchange: socialization, externalization, combination and internalization, as represented on the Figure 3. Knowledge socialization refers to the creation of new *tacit knowledge* from shared tacit knowledge. Knowledge externalization refers to the conversion of *tacit knowledge* into *explicit knowledge* [27]. Knowledge combination refers to the creation of new knowledge through the exchange and combination of *explicit knowledge* held by individuals in the organization. Knowledge internalization takes place when *explicit knowledge* becomes tacit, in a way similar to learning.

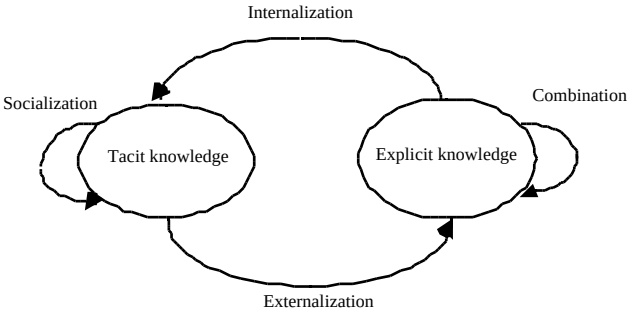

Figure 3 : Movement between tacit and explicit knowledge

We think that the main contribution of Nonaka is beyond the distinction between *tacit and explicit knowledge* by the study of the exchanges between these two types of knowledge. The process of externalization is especially interesting as regards context for it anticipates on the process of proceduralization that we have introduced in [31]. This rises the question of why and when people decide to externalize. This question is particularly important in process control because the development of automatic control systems supposes that *knowing how* has been previously captured. *Knowing that* may explain parts of *knowing how* but is never sufficient to control complex process whence the idea of cooperative or interactive systems in which operators work in interaction with a system. For example, mechanics laws can explain how and why bikes run but a bit of practice is necessary to ride a bike. This last example shows that the links between deep knowledge and practice are never necessary because many people ride a bike wihtout any idea about mechanics.

If we were obliged to distinguish between the two types of knowledge, we would conclude that the AI community made a good point about *deep* and *surface knowledge.* Our observations in engineering and process control lead us to emphasize the distinction between *deep knowledge* and *know how*. As regard *know that* we believe that this notion can be assimilated to *deep knowledge* but we prefer the latter because it captures the fact that *this knowledge is generally not immediately sensible.*

The distinction between tacit and explicit is also important whereas we believe that any kind of knowledge can be made explicit or implicit depending on the circumstances, the persons and the society. This is the reason why we prefer to stress the question of how to make explicit hidden *know how* even if we guess that there is a part of *knowing how* which is definitely non explicitable. These are the central questions for developing "intelligent" assistant systems [4].

One of the last characteristics of *know how* which have already been recognized is that *know how* is task specific [36] and is related, whereas not similar, to ability [32, 8, 36]. The AI community introduced the term of *situated action* [9]. This rises the question of the acquisition of the context of the *know how* and of the validity of the *know how*. For example, somebody may have *know how* for sailing in a bay and may have great difficulties on open sea with a bad weather. In other words, *knowing how* gives some abilities which are dependent on the context of application. Thus, before we examine the relationship between context and knowledge, let us remind some basics about context.

CONTEXT

A survey in AI shows that there is already a large amount of discussion about context (e.g. see [3]). From an engineering point of view we can start from a definition of context as the collection of relevant conditions and surrounding influences that make a situation unique and comprehensible.

Let us take an example, in the control of a subway line [4], where a large amount of knowledge about trains, electricity, people reaction, etc., contributes to make the situation unique, while some more particular conditions about the time, the day, the weather and so on, influence specifically many decisions. In other words, there is a common background context which is then specified by some conjecture and contingent influences. For example, the general context is subway control which differs from train or bicycle control although they share some mechanical laws and the particular context is specific to a line, a day, an hour, etc. These considerations explain why context can be defined as the whole set of secondary characteristics of a situation or secondary properties of a cognitive or motivational state of an individual which may modify the effect of an effective stimulation (stimulus) or an oriented activity [35].

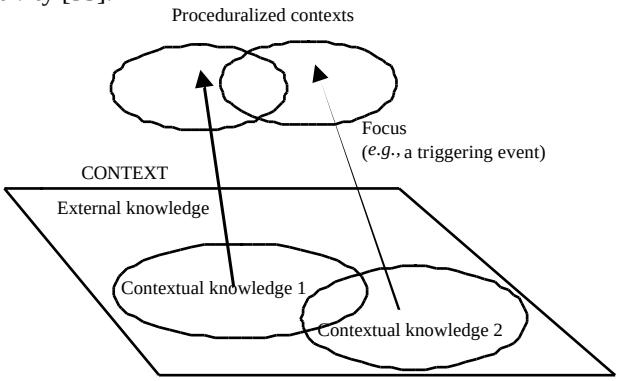

Figure 4: Contextual knowledge and proceduralized context

Thus, it would probably wise to talk of primary and secondary context to distinguish between the general, relatively fixed primary characteristics of a situation, and the secondary characteristics which are more mobile. If we think about primary context, we must confess that it is difficult to avoid the word knowledge about this general background used by the operators to carry out their task. This is the reason why we have proposed [4] to call "contextual knowledge" the primary or back-stage context.

Therefore, at a given step of a decision process or of a task performing, we distinguish between the part of the context which is relevant at this step of the decision making or task performing, and the part which is not relevant. The latter part is called *external knowledge*. The former part is called *contextual knowledge*, and obviously depends on the agent and on the decision at hand. At a given step of the decision making, a part of the *contextual knowledge* is proceduralized. We call it the *proceduralized context.* The *proceduralized context* is a part of the *contextual knowledge* which is invoked, structured and situated according to a given focus. In our field studies about the task of incident solving, we observed that a part of the *contextual knowledge* is known *a posteriori*, since some elements appear to be important to understand, explain or solve the incident only during the incident solving, not beforehand. This observation is similar to Edmonds's view [14] for which it is better not to distinguish context from other objects of reasoning, learning, etc., objects being in the context or not according to circumstances. For a given incident, the frontier between the subset of *contextual knowledge* and the subset of *external knowledge* is fixed, we just don't know, before the incident, if an element is a part of *contextual or external knowledge.*

The *contextual knowledge* is a backstage knowledge whereas *proceduralized context* is immediately useful for the task at hand. In our representation of context, the *contextual knowledge* is largely tacit, mainly because it is the context that everybody knows without expressing it. In a distinction reminiscent to cognitive ergonomics [22], we could say that the contextual knowledge is useful to identify the *activity* whereas the proceduralized context is relevant to characterize the task. It is also worth noting that one observes that tasks correspond to the explicit aspect of the work while activities are rather implicit [22]. The distinction between practical and theoretical knowledge or *knowing how* versus *knowing that* is not relevant here. The *contextual knowledge* can encompass both types of knowledge.

An important issue is the passage from *contextual knowledge* to *proceduralized context*. This *proceduralization* results from the focus on a task. Thus, it is task-oriented just as *knowing how*; it is often triggered by an event or primed by the recognition of a pattern. Another aspect of *proceduralization* is that the operators transform contextual knowledge into some functional knowledge or causal and consequential reasoning in order to anticipate the result of their own action. Thus, the functionalization is a part of the *proceduralization process*, and this is the reason why we

have chosen that term of *proceduralization*. This *functionalization, or 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 [30]. The second step needs a conscious reasoning about causes and consequences.

A second *proceduralization* aspect is a kind of instantiation. This means that the contextual knowledge or background context needs some further specifications to perfectly fits the task at hand. These precisions and speciation brought to the contextual knowledge is also a part of the *proceduralization* process.

Finally, a last point deserves attention, it is the role of context in knowledge acquisition. Wilson [37] defines information as data plus context. Accordingly it would be the context which supports data structuration and makes them readable to human beings. We cannot share this view because we cannot see how context can intervene *per se*, we think that people transform data into information and this transformation depends on the context but relies on knowledge. We are closer to [39] who states that data represent observations or facts out of context and that context is one of the elements of the transformation into information. Another view is that "knowledge is generated when information is combined with context and experience" [15]. We certainly agree that, on the one hand, experience is a part of knowledge construction. On the other hand, Karsenty and Brézillon [18] point out that the context intervenes in learning. However, once more, we think that even if the context is necessary to "situate" knowledge and if what is learnt must be re-used in the context of acquisition, we do believe that an important part of knowledge is either non-contextual or de-contextualized in the mind. This is one of the reasons why we think that knowledge is not as appropriate as context for system design as we will explain in the next section.

CONTEXT IN DECISION AND ACTION

The first distinction between context and knowledge or information is that context is *task-oriented* or is, at least, related to an activity [23]. All the authors we reviewed using the notion of context relate the notion to some specific framework of decision and/or action. For example, the fact that we know that the nearest star after the sun is *Proxima Centauri* at 4.22 light-years will never be *contextual knowledge* except for an astronomer or people engaged in star trek! Whether it is backstage contextual knowledge or immediately usable knowledge, depends on what a subject intends to do. So, the context is primarily *subjective*, even if it can be shared in a community according to the process previously described.

These two characteristics (1) task oriented and (2) subjective are also two components of *know how*. This does not mean that the two concepts are similar, since the *contextual knowledge* can contain some theoretical knowledge. For example, in many tasks, a contextual element which is taken into account is the gravity. By the way, this element is typically not a secondary specification and is therefore a part of *contextual knowledge*, moreover the intensity and the role of gravity is obviously a matter of theory. We therefore think that the context is not reduced to *surface and declarative knowledge* and can also involve *deep knowledge*.

Context is task oriented or more precisely the proceduralization process is task-oriented even *task-focused* and/or *recognition-primed*. During this passage from back to front stage some information are instantiated, this is like new information that is provided about the events in a uncertain setting. At a given moment, we do not know the true nature state, then after a while, some events are known which give more information on the true nature state. According to this comparison, in our model, a context has many possible realizations just as an event in decision theory. This means that the *contextual knowledge* has many variables and that the proceduralization process is partly an instantiation process. One can say that *knowing how is instantiated in doing*. The *proceduralized context* is an instantiation of a part of the *contextual knowledge*. This instantiation gives the keys for decision making or action. *Proceduralized context* is sufficient for action but only people with the adequate *knowing how* can bridge the gap between *proceduralized context* and action. The *proceduralized context* triggers some entailment links for people *knowing how*. As such it can be regarded either as a part of *know how* or as a signal triggering adapted answers to a situation.

The relationships between the *proceduralized context* and decision making or action are not necessarily explicit. A kind of compilation can occur that establishes some routine links between a *proceduralized context* and the subsequent action or anticipation. This is the functional side of the proceduralization.

KNOWLEDGE AND CONTEXT

To sum up, the differences and analogies between context and knowledge, are:

- context and knowledge can be *explicit* or *implicit*, but both can be explicited except for some parts of *know how*
- context can contain *deep* and/or *surface knowledge*,
- the *contextual knowledge* is loosely task-oriented not reduced to *know how*, because it may contain *deep knowledge*,
- the *contextual knowledge* is mainly concerned with this part of knowledge which is useful for describing the nature state preceding decision making or action; as such a given *contextual knowledge* may have several realizations,
- the proceduralization of a *contextual knowledge* piece is a subjective process which is a mandatory step on the road to action. As such, it has a role in diagnosing the

situation, priming action or practice. In some sense, it is the preliminary step for the activation of *knowing how*. In some case the proceduralization can be a shared process within a community,

- the *proceduralized context* is task-oriented or/and recognition-primed and subjective like *know how* or *situated knowledge*,
- the link between *proceduralized context* and action is either explicit or implicit (compilation of the *proceduralized context*). As such, the *proceduralized context* is relevant to the so-called externalization process [26]. This externalization process is more or less a social process,
- whereas the knowledge is fixed, the *proceduralized context* changes during action.

Thus, it is clear that context and knowledge have many similarities and links, but they nevertheless differ. Context is different from *knowing how*, but is similarly subjective and task-oriented. Context is mainly descriptive knowledge more or less used to describe nature states but can contains a part of *deep knowledge*. *Contextual knowledge* obeys to a dynamics of instantiation and functionalization during action. Finally, we do believe that knowledge is a too vague concept to be really operant in the analysis of decision making and of task undertaking. On the contrary, the notion of context which is entirely task oriented offers a shrewder concept to model the relationships between knowledge and action.

CONCLUSION

The notion of context offers an alternative view to *knowing how* to capture that part of knowledge which is related to decision making and action. *Contextual knowledge* is subjective and yet can be shared by many individuals. One of the main difference between context and knowledge is that context and its proceduralization offer a model to understand the links between decision making and/or action and the backstage knowledge used in a given activity. The notion of context does certainly not explain *know how*, but it helps to understand how experienced people with a recognized *know how* adapt their behavior according to the circumstances. In some sense, context is knowledge about the instantiation of *know how*, it is the framework which reveals *know how*.

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