Comparison of Approaches toward Formalising Context: Implementation Characteristics and Capacities

William Loyola
Escuela de Postgrado en Administración de Empresas, Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador
wloyola@espol.edu.ec

Abstract: Existing relevant literature regarding approaches to context formalisation is analysed in search of a characterisation that explains the links - suggested by knowledge theory of the firm - between knowledge integration capability and common knowledge types. The ontological and the syntactic-semantic-pragmatic continuum approaches reveal an extensive description of context, which contributes to the understanding of the knowledge integration process, and to an eventual operationalisation of common knowledge types. This theoretical development opens possibilities for the elaboration of prescriptive models that support the integration of knowledge during routine operations of the organisation.

Keywords: knowledge integration, common knowledge, context formalisation

1. Common knowledge in management

One relevant proposition of the knowledge-based theory of the firm is that the ability of an organisation to integrate existing knowledge builds up its competitive advantage. The capacity to integrate existing knowledge, not the knowledge itself, is emphasised here (Grant, 1996). Another theorist, Schendel (1996), proposes that developing new organisational knowledge creates competitive advantage. With a different vocabulary, but referring to same concepts of organisational knowledge, March (1991) and Spender (1992) refer to "knowledge exploitation" as the application of existing knowledge to deliver goods and services and to "knowledge exploration" as the generation of new knowledge. According to all of these theorists, there is a consensus that knowledge is a key component of organisational capability, whether in the exploration or exploitation approach. This work will elaborate on the knowledge exploitation approach. The postulate that integration of existing knowledge to deliver goods and services in organisations relies upon common knowledge for their undertakings is voiced by Grant (1996). In this same line, Nonaka and Takeuchi (1995) refer to common knowledge as "redundancy" that allows a loose coupling among members of a group. In the communications literature Cramton (2001) refers to "mutual knowledge" as the knowledge that the communicating parties share in common and know they share (Krauss and Fussell 1990), that is the "common ground" integral to the coordination of actions (Clark, 1996). Grant adds that common knowledge is constituted by those elements of knowledge that are common to the members of an organisation; namely, the intersection of their knowledge sets and enables the sharing and integration of the aspects of their knowledge that are not common to all of them. Common knowledge, here, accepting these Deweyan pragmatic approaches, is the kind of knowledge that makes members of the organisation communicate well, avoid misunderstandings, and be able to solve business problems together.

Grant (1996) goes further, he identifies different types of common knowledge and argues for a positive relationship between the level and sophistication of common knowledge types - common language, shared meaning, and recognition of individual knowledge domains - and the efficiency of the knowledge integration process, In spite of Grant's convincing arguments it is problematic to understand and corroborate such relationships given the broad scope of the independent variables: common language, shared meaning and recognition of individual knowledge domains. To my best of knowledge, considering this pragmatic view, a set of operational measures have not been proposed nor tested to support or not the theory. This paper looks into existing approaches to context for the understanding of these common knowledge types with the purpose of giving them a tractable and consistent scope.

2. Common knowledge and context

While organisational common knowledge is described as the common collective knowledge of the members of an organisation, the reference domain to which this knowledge is common has been admitted as a tacit issue but without adequate explanation. Common knowledge is common in regards to what is widely shared among members of a group, community or organisation: their context, their environment.

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Here, the idea of "context" is chosen over "environment" given that it denotes a stronger link to language and meaning than the idea of "environment". So, in advocating for an approach for understanding the knowledge integration process in organisations it is necessary to understand the domain to which common knowledge types - common language, shared meaning, and recognition of individual knowledge domains - belong to; that is, the understanding of "context" in organisations. Conceptualisations of knowledge in organisations (Davenport and Prusak, 1998; Bell, 1999; Tsoukas and Vladimirou, 2001) (see section 4) include context as key part of their explanations and even they denote a role to it. However they do not elaborate on the definition of the concept, neither in its specification. In such situation, considerations to the general definitions of "context" are in order.

The Webster's English Dictionary tell us that context is a) "the parts of a discourse that surround a word or passage and can throw light on its meaning", and b) "the interrelated conditions in which something exists or occurs". It is acceptable to conclude that these acceptations of context relate to narratives, situations, and events, their relations to its surroundings and the possibility of inferring meanings from them. This starting point achieved to identify essential properties belonging to the concept of context, however they do not bring yet sufficient light to the problem of providing a tractable and consistent scope to common knowledge types.

3. Analysis of approaches toward formalising context

It is necessary at this point to look into existing approaches to context in order to reveal how context - the domain to which common knowledge is common - characterises common language, shared meanings and recognition of individual knowledge domains. Context is a concept that has called the attention of many disciplines - philosophy, history, psychology, cognitive science, linguistics, information science, organisational sciences, artificial intelligence - and there is even an interdisciplinary conference dedicated to the modelling of context. However, the disciplines of information science and artificial intelligence are the ones that have made the most significant contributions to its formalisation. This literature review will look into approaches to context that try to formalise its externalisation, that is, its structure and content. Three publications, Akman and Surav (1996) with "Steps toward Formalising Context", Brézillon (2002) with "Modelling and Using Context - Past, Present and Future" and finally Strang et al (2004) with "A Context Modelling Survey" provided the elements to assemble a schema for the understanding and evaluation of approaches. Representative proposals for each model are described and critically evaluated from the common knowledge type perspective (see Table 1).

Key-Value Model, (Schilit et al, 1994) allows a basic representation of context. The most it can be expected from it, a structure that offers an identifier and its value for each element constituting context, is the capacity to share a list of terms related to a situation or event (a basic form of common language). Markup Schema Model (Held et al, 2002) allows publishing of an inventory of elements related to a context by means of tags and associated attributes following a schema that describes context structure (a proxy to common language and a basic form of sharing meanings). This approach separates context schema from its content; however new contextual relationships are complex to incorporate (it asks for markup language expertise).

Object Oriented Model (Schmidt et al, 1999) exposes the properties – names and values – of a context and relationships among properties – thru events and methods - following a class model that describes context structure (a proxy to common language and a basic form of sharing meanings). This approach separates context structure from its content and allows reusability of existing context structures, however extensibility of a context structure is complex to achieve (it asks for object oriented programming knowledge). The main motivation for studying contexts in artificial intelligence is to approach the problem of generality brought by McCarthy (1987). This problem is exemplified by McCarthy through a system that advise physicians on treating bacterial infections of the blood and meningitis; system which has embedded rules for recommending two weeks of tetracycline treatment and nothing else to a patient case that has cholera vibrio in his intestines. These rules resulted in a case where patient would die long before the bacteria are gone due to the diarrhoea. The traditional approach to correct this flaw would be to add a rule to specific cases so it considers the diarrhoea symptom. As an alternative, a general approach is to incorporate patient contextual information – including symptoms - so that the system can use it for all cases. In this case, considering contexts explicitly ease the knowledge integration process.

Main implementation Approach	Key-Value Model	Markup Schema Model	Object Oriented Model	Logic Model								Graph Model		Ontology Model
				First-order logic				Modal Logic	Extended Logic	Model Based	Rule Based	UML Diagram	Contextual Graphs	
Representative Research / **Adapted from** Akman & Surak (1996) / **Implementation Characteristics**	Schilit et al (1994)	Held et al (2002)	Schmidt et al. (1999)	McCarthy (1993)	Guha (1991)	Giunchiglia (1993)	Attardi and Simi (1993)	Shoham (1991)	Buvac and Mason (1993)	Barwise (1986); Akman and Surav (1996)	Clancey (1983); Brézillon (1999)	Henricksen et al (2003)	Brézillon (2002)	Strang et al (2003)
Context definition supports logic	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Context definition is guided by pre-established model	No	Yes	Yes	No	No	No	No	No	No	Yes	No	Yes	Yes	Yes
Context definition is guided by rules	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No
Context definition is based on/use graphs	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No
Context definition uses a markup language	No	Yes	No	No	No	No	No	No	No	No	No	Yes	No	Yes
First-order logic deduction mechanism	No	No	No	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No
Modal Logic deduction mechanism	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
Free of self-contradictory statements	No	No	?	No	No	Yes	Yes	Yes	Yes	?	No	?	No	No
Circular definitions avoided	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Evaluation of Capacities	-- Not available, - Limited, + Functional, ++ Flexible													
Formalization of common language	-	+	++	+						+	++	++		++
Formalization of shared meanings	--	-	-	+						+	+	++		++
Formalizing recognition of individual knowledge domains	--	--	-	-						+	+	--		++

Representative Research

Akman & Surav (1997) The use of situation theory in context modeling.
Attardi & Simi (1993) A formalization of viewpoints.
Barwise (1986) Conditionals and conditional information.
Brézillon (1999) Context in human-machine problem solving: A survey.
Brézillon (2002) Modeling and Using Context - Past, Present and Future.
Buvac & Mason (1993) Propositional logic of context.
Clancey (1983) The epistemology of a rule-based expert system.
Giunchiglia (1993) Contextual reasoning.
Guha (1991) Contexts: A formalization and some applications.
Held et al (2002) Modeling of context information for pervasive computing applications.
Henricksen et al (2003) Generating Context Management Infrastructure from High-Level Context Models.
McCarthy (1993) Notes on formalizing context.
Schilit et al (1994) Context-aware computing applications.
Schmidt et al (1999) There is more to context than location.
Shoham (1991) Varieties of context.
Strang et al. (2003) Applications of a Context Ontology Language.

Table 1. Comparison of existing approaches toward formalizing context - Implementation characteristics and capacities

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Logic Model (McCarthy 1993; Barwise 1986; Guha 1991; Giunchiglia 1993; Attardi and Simi 1993; Shoham 1991; Buvac and Mason 1993) approaches from artificial intelligences allow sharing of well formed propositions - first-order logic or modal logic - about context (a proxy to common language), consistent evaluation of contextual propositions (a proxy to share meanings) and identification of expertise (recognition of individual knowledge domains). However, with the exception of situated theory framework (Barwise 1986; Akman and Surav 1996), logic model asks that members of the organisation have to decide by themselves what constitute a contextual proposition in order to formalise a particular context. In the other hand, logic model using situated theory framework has the advantage of offering a contextual schema (time, location and participants) besides the capacity to add contextual propositions to the specific context. Logic Model approach merges in the positions the structure and content of context, a model that makes new contextual relationships complex to incorporate, especially if predicate calculus is not part of the common knowledge of the organisation. Rule-based model (Brézillon, 1999) approach to context representation is described by its well-known example of a screening clause (Clancey, 1983), which succinctly exemplifies its implementation strategy. If

- The infection which requires therapy is meningitis,
- Only circumstantial evidence is available for this case,
- The type of meningitis is bacterial,
- The age of the patient is greater than 17 years old, and
- The patient is an alcoholic,

Then: There is evidence that the organisms, which might be causing the infection, are diplococcus-pneumoniae (.3) or Escherichia coli (.2). In this case Brézillon (1999) points out that clause 4 acts as a screening clause which sets the rule as valid in the context of an adult, it is a constraining clause that does not arbitrate in the problem solving, it just define the applicable context. It should be obvious at this point that the Rule-based approach uses natural language syntax in contrast with the mathematical syntax of the Logic Model approach. Context structure in this approach is blended in, and described in terms of the problems it helps to confine. Contextual Graph Model (Pasquier, 2000; Brézillon 2002) is proposed as a unifying framework that associates explanation, learning and knowledge acquisition. The subjacent logic of contextual graphs resides in the classification of the knowledge needed for a decision to be made: a) Proceduralised context: “knowledge that is shared by those involved in the problem and is directly but tacitly used for the problem solving”, b) Contextual knowledge: “knowledge that is not explicitly used but influences the problem solving” and c) External knowledge: “knowledge that has nothing to do with the current decision making step but is known by many of those involved” and d) Context: the sum of all the knowledge possessed by the decision makers on the whole task (Figure 1).

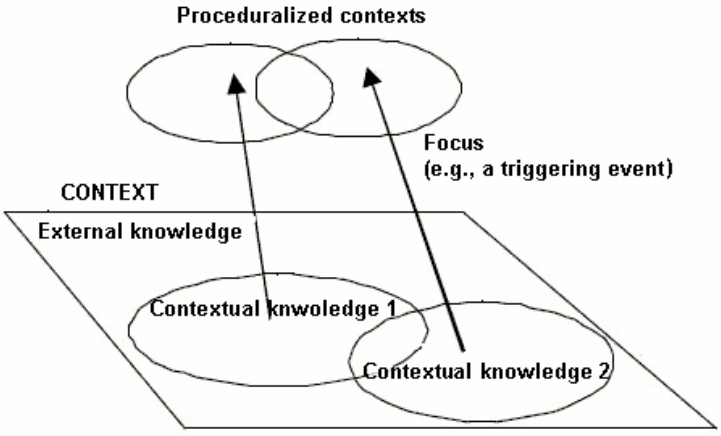

Figure 1. Diferent type of Contexts. Brézillon (2002)

Based on this framework, Pasquier (2000) proposes a contextual graph to represent the actions to carry out according to the context of an incident. This is an acyclic graph, in which the action nodes (rectangles) represent actions to carry out to achieve a goal while the event nodes (circles) become contextual nodes describing the possible contextual issues of a specific event. Contextual graph represents the part of the context that has been proceduralised. Proceduralised context is compiled knowledge that can be decompiled to explain its reasoning.

Cognitively speaking, the scarcity principle leads to try to reuse well-known procedures as soon as possible thru macro-action (MA rectangles) or sub-graphs (bigger rectangles).

At first glance, contextual graph could be thought as a notation to draw incident workflows, but its proposed framework, based on focal and subsidiary knowledge (Polanyi, 1962) does describe a knowledge externalisation model that looks for customary incident handling thru the characterisation of context and embedded self explanation. A contextual graph is a prescriptive approach that helps the understanding of the level and sophistication of all common knowledge types; however it requires incident by incident context structuring. Finally, Ontology model (Otzturk and Aamodt, 1997; Strang et al, 2003) is an information systems approach to context formalisation. Ontology, as described by Smith (2003), is the inventory of relevant entities of a domain externalised as a vocabulary of the terms that denote these entities with their commonly accepted, concise and unambiguous definitions. The formalisation of the vocabulary varies from loosely expressed in natural language to meticulously defined terms with formal semantics recurring to first-order logic or modal logic (Uschold and Gruninger 1996). In this sense, the Ontology Model to organisational context argues for a syntactic and semantic standardisation of shared and consensual knowledge structures (a proxy to common language and shared meanings) related to corporate competencies (Vasconcelos et al, 2000) to describe everyday information (Strang et al, 2003).

These knowledge structures, proposed as taxonomies, have differences within in their composition, however general consensus in some characteristics of the taxonomy of real objects exists (Chandrasekaran et al, 1999): 1) there are objects in the world, 2) objects have properties that can take values, 3) objects can exist in various relations with each other, 4) properties and relations can change over time, 5) there are events that occur at different time instants, 6) there are processes in which objects participate and that occur over time, 7) the world and its objects can be in different states, 8) events can cause other events or states as effects, 9) objects can have parts. Existing ontological models to context (Otzturk and Aamodt, 1997; Strang et al, 2003) show similar implementation characteristics than the Logical Model approach; however the ontology approach, in general, proposes an abstraction layer by means of context taxonomy, and a context content mechanism which needs not to be technologically approached but systematically approached which is more likely to be part of common knowledge in organisations.

In summary, the critical evaluation of the approaches from the common knowledge type perspective, reveals that: a) Key-Value Model capacity is limited to share an inventory of terms about situations or events without meanings associated to them; b) Markup Schema Model separates context structure form its content and allows sharing of a friendlier common lexicon thru a pre-established context model; c) Object Oriented Model has similar characteristics of previous model but differs in that context structure extensions requires object oriented programming knowledge; d) Logic Model offers proxies to the three common knowledge types but dealing with the context structure and content ask for a not very common knowledge language for management: predicate calculus; e) Rule-based Model has similar characteristics of the previous model but with a natural language interface, yet still blends context structure and content which prevents the sharing of context; f) Contextual Graph model is a knowledge theory based prescriptive model which provides a notation to draw incident workflows that incorporates contextual information and helps in the understanding of the common knowledge types, however it requires incident by incident context structuring; and finally the g) Ontology Model, which is a general purpose model characterised by a meta-structure that describes syntactic and semantic sides of context, separation of context structure and content, and a systematic and not necessarily technological implementation approach. The reviewed approaches to context formalisation offer different levels of characterisation to common knowledge types; however the ontological approach provides the most descriptive capacity and consistent scope given its structure (guidelines for context taxonomies) and context content (procedures of definition).

4. Knowledge and context conceptualisations

This section will work on conceptualisations that argue in favour of characterising context as a boundary object (Star, 1989). These conceptualisations will help on the understanding of the links between common knowledge types and knowledge integration capability. A boundary object, basically, is an artefact (physical or mental) that allows members of different practices to share common grounds (Arias and Fischer, 2000). Boundary object supports the distinguishing of differences but also provides

common points of reference (Harvey and Chrisman, 1998).

Knowledge management research makes use of the boundary object abstraction to explore the interactions between knowledge and people. Carlile's (2004) "integrative framework for managing knowledge across boundaries when innovation is desired" is one relevant research example that presents a case of an "automobile clay model", considered as boundary object, to explain the dynamics of the knowledge exploration approach. Carlile (2004) recalls Shannon and Weaver (1949) seminal work on information theory, which describes the three levels of communication complexity. Shannon and Weaver relate the available repertoire of distinct symbols and their syntax - rules between symbols - to the syntactic or technical level of communication. Then, they identify the process by which symbols actually get meaning as the semantic level; and finally, they consider the desired effect of a particular message on a message destination as the effectiveness or pragmatic level. Even though Shannon and Weaver avoid much elaboration on the semantic and pragmatic level of communication, these three boundaries – syntactic, semantic and pragmatic – have been referenced by several authors as a boundary framework for the analysis of data, information and knowledge, correspondingly (Carlile, 2004; Boisot and Canals, 2004). Carlile argues that in order to achieve novelty different capabilities are needed at different boundaries of communication. The transferring capability asks for the development of common lexicon, it deals with the syntactic issues; the translation capability takes care of semantic issues and asks for the development of common meanings and the transformation capability ask for common interest, that is the pragmatic level (see Figure 2). Here, I am ready to accept Carlile's knowledge exploration framework and at the same time I argue for a search of a knowledge exploitation (integration) framework linked to an understanding of context as the boundary object.

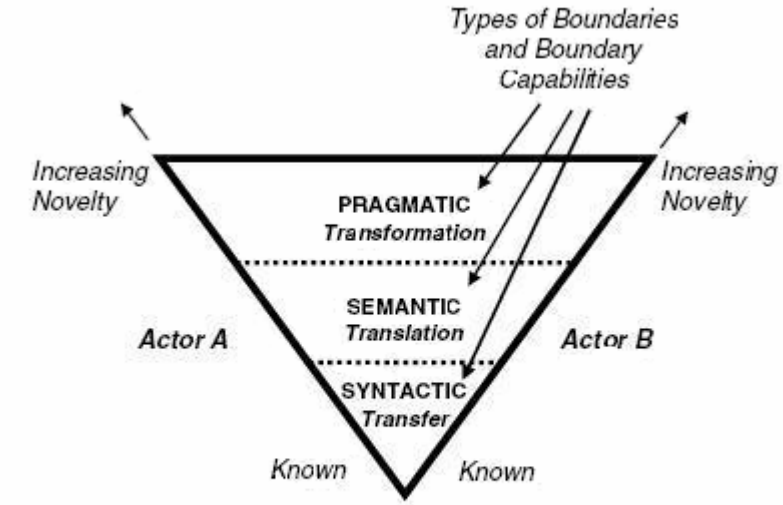

Figure 2. Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries (Carlile, 2004)

Choosing to follow this theorising approach – the data-information-knowledge continuum – is not fortuitous; it involves the need to describe domains and boundaries of common knowledge in doing so it is necessary to consider the existing explanations regarding this continuum. Ackoff (1989) defines data as "raw … it simply exists and has no significance beyond its existence … it can exist in any form, usable or not … it does not have meaning of itself" and posits that information is "data that has been given meaning by way of relational connection ... meaning can be useful, but does not have to be", and that knowledge is the application of data and information. Ackoff emphasises the assignment of semantics and relations to information, and states that knowledge is instrumental; but his definition of data does not tell us much. Davenport and Prusak (1998: 2) posit that "data is a set of discrete, objective facts about events" and that "Unlike data information has meaning" (1988: 4), and describe knowledge as "a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers" (1988: 5). Davenport and Prusak suggest human involvement and relationships among data to define information – contextualised, categorised, calculated, corrected, condensed - and at a

personal level they describe knowledge as an individual capability to capture more information. In a way, they describe knowledge as a complicated, and not very clear, mixture of processes that incorporates contextual information; but still data is not yet well described. Davenport and Prusak also posit that knowledge "In organisations, often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices and norms" (1988: 5). The position here is that knowledge is personal and that Davenport and Prusak are confusing knowledge with representations of data and information.

Bell (1999) has a more integrated description of this continuum. He states that data is an ordered sequence of given items and events, that information is a context-based arrangement of items and their relations, and that knowledge is the judgment of the significance of events and items which comes from a particular context and/or theory. In the case of Bell's knowledge definition it is revealing that a judgement of the significance of information can be based on context and not only on theory. I will come back to this issue later on. However, it is the work of Tsoukas and Vladimirou (2001) that stresses the ideas behind this continuum. In their research case at a customer care department at Greece's leading telephone provider, the personnel at the customer care department were exposed in their work to a lot of discrete items (names, addresses and phone numbers) and business rules (if <problem> then <check this or that>) where their use required a certain level of judgment; departing from here and by means of experience, operators discovered from verbal hints that they were dealing with an unhappy or perplexed customer and acted according to the circumstances, adapting the business rules to the context of their conversations. This case reveals that the level of human involvement (Tsoukas and Vladimirou, 2001) – identifying phone numbers, selecting applicable business rules and adapting action to the particular context – explains the data-information-knowledge continuum and the relevance of context in this continuum.

In a different, but consistent, line of research, Boisot and Canals' (2004) proposal, after their revision of information theory and social studies, is consistent with the level of human involvement identified by Tsoukas and Vladimirou (2001). Boisot and Canals (2004: 62) state that "Effective cognitive strategies extract information from data and then convert it into knowledge. Effective cognitive and behavioural strategies vary from agent to agent as a function of their situation, of their prior individual knowledge …" making explicit the cyclic aspect of the continuum and show that the outcomes of information and knowledge extraction depend on the effectiveness of human involvement. Analysing the assessments of this continuum, it can be argued that its description accomplishes the identification some basic categories of data: items and events, which can be related to the interrogative primitives "what/who" and "when/where" and that perception is the type of human involvement linked to data. Boisot and Canals (2004) are explicit about perception when they posit that perceptual filters guide the senses to certain types of stimuli and only stimuli passing through this filter get registered as data.

The issue of perception involves a neural processing that takes place between the reception of a stimulus and its sensing as data by an individual (Kuhn, 1974). Appealing to Shannon and Weaver (1949), it can be added that data is registered using an agreed established symbolic repertoire and syntactic rules – alphabet, vocabulary and the language syntax rules (Boisot and Canals, 2004). So data is conditioned by each individual's perceptual filters and at the same time it is referenced by means of an agreed shared language – an inter-subjective objectivity (Popper, 1959). But, where does this agreed shared repertory come from? Polanyi (1966) argues that our knowledge of the things denoted by words will have been largely acquired by experience – mental or physical; so these words incorporated in discourses, or associated to situations or events were previous experiences in the chain of perceptual filters and it's sensing. The extension of the use of language when referencing data is mnemonic and syntactic, that is, we attach a name to each datum and use it following syntax rules, but in order to name data a certain level of human involvement has to be applied (Tsoukas and Vladimirou, 2001), we need to discriminate between "this" and "that" (Dewey, 1934). Then, the reference to data through language implies that data is part of a recurring process, as posited by Boisot and Canals (2004), who propose that our perceptual filters are affected by our existing knowledge.

Considering the achieved understanding of data and the given acceptations of context, it could be said that:

> *Perceived context is data about the entities that have been sensed and filtered from a discourse, situation or event – mental or physical experiences – by the individual, and referenced by a mnemonic and syntactic common language via a process of discrimination; then, perceived context is*

characterised as a sequence of the what, who, when and where of experiences.

Ackoff (1989) relates information to meaning; Davenport and Prusak (1998) suggest relations between data to define information; Bell (1999) links information to context-based interrelated data; and Boisot and Canals (2004) assert that extracting information from data constitutes an interpretation of data according to some pre-established mental models. These descriptions imply the individual capacity to discover relations between data and assign meaning to them, whether in reference to context or mental models or both. This latter assessment requires some elaboration. Mental models theory (Byrne 1991) focuses on semantic procedures and explicit formal rules of inference and it has been tested that context helps the finding of counterexamples of presumed conclusions (Byrne, Espino and Santamaria, 1998); from here it can posited that one role of context is to assist formal mental models. In the other hand, there are theorists of natural logic like Politzer and Braine (1991) who argue that the mind is provided with tacit rules of inference. They tested that changes in context facilitate performance on conditional reasoning tasks; from here it can be posited that another role of context is to assist the tacit rules of inference.

Thus, the capacity to discover – infer – meaning from data – in general - is principally guided by formal explicit rules of inference and subsidised by perceived context, and that in this discovery meaning carries information. Complementarily, as a subset, the capability to discover meanings from perceived context is principally guided by tacit rules of inference, and this discovery of meanings carries contextual information of a specific experience – discourse, situation or event. "How" and "why" are posited as propositions that help to describe the meanings discovered, establishing relationships between the what, who when, and where of the data in general and perceived context in particular.

Summing up, contextual information involves the inference of meanings from data of a specific experience; these meanings are discovered guided mainly by tacit rules of inference, base on the interpretation of examples and counterexamples. Namely, contextual information is characterised by the interrelated what, who, when, where, how and why of a specific experience.

Once that an understanding of context have been established at the synthetic (perceived context) and semantic (contextual information) levels, the exploration of knowledge theories may shed light on the pragmatic level of context. Recalling from earlier, for Ackoff (1989) knowledge is instrumental; Davenport and Prusak (1998) describe knowledge as a capability for using experience, values, contextual information, and expert insight, to evaluate new experiences and information. Tsoukas and Vladimirou (2001: 976) is a more enlightening reference work to depart from, they dissect Bell's (1999) description of knowledge - the judgement of the significance of events and items and that this judgement can be based on context and not only on theory – and argue for incorporating the idea of "domain of action" to propose a definition that states knowledge as the:

"Individual capability to draw distinctions, within a domain of action, based on the appreciation of context or theory, or both" (Tsoukas and Vladimirou, 2001).

This definition merits some consideration. Tsoukas and Vladimirou (2001) supported in Polanyi (1962) and in a Wittgensteinian view, posit that to know how to act within a domain of actions is to make competent use of the distinctions constituting that domain. *Domain of actions* is a generalisation that refers in terms of organisations to the community of a specific scientific or professional practice. Within this specific domain – practice – is where the standard of knowledge is measured through theory and/or context. Social construction of reality (Schutz, 1970; Berger and Luckmann, 1967) is brought to our attention to argue in favour of context equipped as theory - "we routinely bring to situations of interaction a tacit awareness of the normative expectations relevant to them and an intuitive appreciation of the consequences that might follow from breaking them" (McCarthy, 1994: 65). Normative expectations and consequences imply shared tacit propositions. It is in this ethnomethodological sense that context supports the capacity to exercise judgement (Tsoukas and Vladimirou, 2001). Anchoring on the knowledge propositions of Tsoukas and Vladimirou (2001) and Boisot and Canals (2004), which capture the most relevant arguments and criticisms regarding the data-information-knowledge continuum, a subset definition of knowledge is posited:

Contextual knowledge *is the individual capability to exercise* judgment and act *based on generalisations discovered mainly by tacit rules of inference regarding a domain of experiences – appreciation of context; that is, based on the appreciation of contextual information regarding a domain of experiences; that is, characterised by the interrelated what, who when, where, how and why about a domain of experiences.*

Contextual knowledge operates, using Polanyi´s terms, as subsidiary knowledge, that is, subliminal and marginal cues that provide the context against which focal knowledge gets its shape (Polanyi, 1962). Summing up, while data and perceived context are related to discrimination capacity and information and contextual information are related to inference, knowledge and contextual knowledge are related to judgment and action. Additionally and in particular, it can be posit that while perceived context and contextual information can be articulated given their syntactic and relational characteristics, contextual knowledge is tacit – given the tacit rules of inference – and corresponds to the domain of what it cannot be easily articulated (Polanyi, 1962). Building upon recognising organisations as three things - historical social communities, real settings where individuals take action and sets of abstract rules - Tsoukas and Vladimirou (2001: 983) proposed a definition of organisational knowledge, which it is, assisted by the arguments regarding the context continuum, extended to make explicit the role of context in organisations.

> Organisational knowledge *is the capability that members of an organisation have developed to exercise judgment and act in particular concrete contexts, by enacting sets of generalisations (propositional statements) based on the appreciation of theory or* historical evolved collective understandings regarding experiences in their practice - *which is based on the appreciation of context - or both.*

From the above definition it is feasible to describe *organisational contextual knowledge*, a subset of the above description:

> Organisational contextual knowledge *is the subsidiary capability that members of an organisation have developed to exercise judgment and act, in particular concrete contexts, by enacting sets of generalisations discovered mainly by tacit rules of inference, base on the appreciation of experiences in their practice; that is, based on contextual information about their practice.*

This conceptual approach reveals an extensive description of context, which is posited as a subset related to the data -information - knowledge continuum: perceived context – contextual information – contextual knowledge.

5. An ontological context continuum approach to knowledge integration

Now, understanding context as continuum and approaching its formalisation from an ontological perspective allows retaking the understanding of the knowledge integration process.

- Increasing the level and sophistication of organisational common language is a syntactic issue that in terms of the context continuum ask for the articulation and sharing of the what, who, when, where of organisational repertories. This articulation is the equivalent of a back-of-the-book index (Pepper, 2002) of what the organisation is about. Like in books, different type of taxonomies can be conceived, each comprising different organisational themes - business lexicon, stakeholders, products concept, services concept, business processes, and technology platforms. In each of these taxonomies there is a list of relevant *organisational terms* and their synonyms. For each organisational term in the taxonomy there are references to the occurrences of specific practice experiences – the "what, who, where and when" of specific experiences. The described organisational taxonomies closely represent the perceived organisational context.
- Improving the level and sophistication of organisational shared meanings is a semantic issue that in terms of the context continuum asks for the discovery of propositions that establish interrelationships among the organisational terms of discourses, circumstances and events. It involves the identification of practice experiences revealed as examples or counterexamples of such a relationship. Briefly, it includes a) propositions that interconnect - associate - topics of organisational repertories – those taxonomies defined to increase the level of common language, and b) the identification of the occurrences of practice experiences linked to the terms that participate in such association.
- Facilitating the recognition of individual knowledge domains is a syntactic and semantic issue; it is related to who knows what. In terms of perceived context, it calls for a) the identification of organisational stakeholders' roles and b) a categorised knowledge domain inventory. In terms of contextual information, it calls for propositions that associate the categories of the knowledge domain inventory with organisational stakeholders' roles. Briefly, this implies a mapping characterised by: a) knowledge domain taxonomies associated

with stakeholder taxonomies, and b) the identification of occurrences of practice experiences - what, who when, where – that reveal examples and counterexamples of such association.

- Integration of knowledge in products and services is a pragmatic issue mainly assisted by contextual knowledge, that is, it implies the use of generalisations and execution of work related activities base on the appreciation of contextual information.

These organisational taxonomies, their associations and the reference to occurrences of practice experiences can be understand as the constituting characteristics of an ontological approach to the formalisation of context and provide a framework for the understanding of the link between common knowledge types and the efficiency of the knowledge integration capability and contribute to its eventual operationalisation.

6. Discussion and conclusion

Knowledge-base theory of the firm argues for a positive relationship between the level and sophistication of common knowledge types - common language, shared meaning and recognition of individual knowledge domains,- and the efficiency of the knowledge integration process which have been proposed to have a link with the strategic advantage view. Considering that in this view, to the best of my knowledge, common knowledge types have not been tested or operationalised and that given the broad scope of these independent variables, this paper takes the challenge to elaborate on conceptual specificity that allows the understanding and formalisation of an approach to common knowledge types that contributes to its eventual operationalisation. In this endeavour, it is necessary to understand common knowledge and their types, but in particular, it is essential to achieve a characterisation of the domain in regards to which "common knowledge" is common. This domain was identified as the organisational context and found that context definition has been admitted as an obvious issue but without adequate explanation. Existing relevant literature reviews regarding approaches to context formalisation were considered in order to compare, analyse and reclassify the context approaches. This effort was a search for the characterisation of a boundary object that explains the links between knowledge integration capability and the identified common knowledge types.

Among the reviewed models, the ontological model, given its capacity to handle all common knowledge types and its general purpose context formalisation mechanism, was the selected approach to elaborate on. The boundary objects approach and the data-information-knowledge continuum approach reveal: a) an extensive description of context - a subset related to the syntactic-semantic-pragmatic continuum; b) a continuum human involvement dependence: data and perceived context are related to discrimination capacity and information and contextual information are related to inference, and knowledge and contextual knowledge are related to judgment and action. This ontological contextual approach contributes to the understanding and eventual operationalisation of the knowledge integration process, as follows: 1) organisational common language is a syntactic issue that in terms of the context continuum requires the articulation and sharing of the what, who, when, where of organisational repertories, 2) organisational shared meanings is a semantic issue that in terms of the context continuum demands a) propositions that relate the topics of organisational taxonomies and b) the identification of the occurrences of practice experiences linked to the terms that participate in such association; 3) recognition of individual knowledge domains is a syntactic and semantic issue; it is related to who knows what. In terms of perceived context, it requires a) the identification of organisational stakeholders' roles and b) the identification of a categorised knowledge domain; 4) integration of knowledge in products and services is a pragmatic issue mainly assisted by contextual knowledge. The ontological context continuum approach to common knowledge does not only configures a proxy to Grant's (1996) knowledge integration process – the case of the knowledge exploitation approach; but also it complements Carlile's (2004) integrative framework for managing knowledge across boundaries when innovation is desired - the case of the knowledge exploration approach. Finally, it opens possibilities for the elaboration of prescriptive models that support the integration of knowledge during routine operations of the organisation.

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