Context Awareness

(position paper)

Christiana Panayiotou

Institute of Computer Science,

Foundation of Research and Technology– Hellas,

Vassilika Vouton, Heraklion, Crete, Greece

email: chrisp@ics.forth.gr

Abstract

Context-Awareness refers to a wide variety of applications. It can be applied in many diverse areas such as logic, decision-making and vision. It is particularly inportant where there is uncertainty or incomplete knowledge of a situation. It is also important where rigid rules are not applicable, and, when it is not possible or relevant to comprehent all potentially useful knowledge. Since most of real world applications have to deal with these type of problems, there is a need to analyse and study thouroughly the notion of context.

Common sense reasoning is often based on the derivation of situation-dependent knowledge. The decisions reached under these circumstances are revised when new information added to the knowledge base renders prior information inapplicable. However, although the concept of *revision* is well understood, there is a need to establish

some quidelines as to whether the right information is used in the right circumstances. In this way, belief revision is constrained to those cases where the information is incomplete. Thus, avoiding the situation where the information is inappropriately used. In order to establish what is appropriate to be considered under each circumstance, we need to identify the context in which the information is selected. Once we do that, we need to establish uniform inference procedures and rules that can be applied to any context. Then, the problem of how to deal with various contexts, needs to be solved .

We believe that there is an increasing need to understand *context*, and then to formalize and axiomatize it. This report is concerned with the notion of *context-awareness* in general with emphasis in the areas of knowledge representation and formal reasoning. This is because we think we need to solve the ontological problem of the notion of *context*, first. However, we recognise the fact that alternative approaches shaded light into many of the problems that would otherwise remain unseen.

1 Introduction

Researchers from different domains are interested in deriving an appropriate definition for *context*. We may need to consider the commonalities of these approaches and relate their differences to the requirements of the environment in which they are intended to operate.

It seems that we are at the footsteps of a new software engineering term: *Context-Awareness*. The intuition is to built applications that reason in a context-sensitive way. The first section gives our definition of context. Important definitions of context are also discussed. In section two, we briefly discuss the relevance of definitions or studies of context to the different areas. In section three, we simply list the areas where *context-awareness* is essential. Section four, analyses some cases where a *context* is useful. Then, we discuss the reasons why we think *context* is useful. Finally, we put down some thoughts which we think are relevant to the problem of implementing a generic supporting infrastructure for context-aware applications.

2 What is Context?

Definition 2.1 *A set of premises expressed in some language, gathered intentionally or unintentionally in a relevant, coherent manner and which can itself constitute an adequate set of inferences (meaningful) or lead to some meaningful results(inferences).*

The language attaches a semantic meaning to the objects of any context. It is important to notice the a difference in the language of representation can cause difficulties in representing the same thing in different contexts. Statements from one language may need to be adapted to express similar statements in another language. Further, we argue that a context can be created intentionally for the accomplishment of some goal, or unintentionally from information received, and, or, processed in an intelligent way. Further, we assume that a set of sentences may constitute a context on their own, or, they may lead to inferences that create a particular context. Following, in this section, is a brief review of the main theories and features about context.

2.1 McCarthy's analysis of Context

McCarthy[6, 7, 8] cited the first attempt to formalise the notion of context and analyse context-based reasoning. The statement:

$$ist(c, p)$$

represents the fact that a proposition p is true in some context c. Contexts are considered as abstract *mathematical objects* which can be either *rich* or *poor*[7]. McCarthy actually addressed the issue of *context* as a problem that needed to be solved, in order to associate queries to a knowledge base and solutions that are best suited to situations, or to the given information. His framework of contextual reasoning gave rise to definitions of concepts that are necessary for almost any context-based reasoning system. For example, the definitions of:

1. lifting axioms,
2. relative decontextualization,
3. trancending between contexts

2.1.1 relative decontextualization

Utterances and sentences are usually tight up to several contexts. For example, references to objects may differ between contexts and statements about truth are valid at one time point and false at another. Further, situations may imply sentences which may not be true in other situations. In contexts not associated with these situations it may not be clear why a sentence derived in another context is true. The process of adding pieces of information to a sentence so that it conveys the same meaning in another context is called *decontextualization*. It is the process of identifying the assumptions that need to be made explicit in a statement so that it carries the same information in another context (or, as much information included in the statement, as it is potentially available and possible to be transferred to another context).

2.1.2 trancending contexts

In many cases we accept the truth of statements whose proof is made in another context, even if we cannot understand the context entirely; at least to the degree of re-inventing the solution or proving its truth. McCarthy[7] refers to the ability to *"comprehend someone else's discovery even if we can't make the discovery ourselves"* as the ability to *transcend* between contexts.

2.1.3 lifting axioms

Rules that relate statements in one context to equivalent or associated statements in another language.

Basically, a knowledge base consists from a set of theories representing the expert knowledge of the system and factual data. Information from different theories may be applicable in a particular case, and therefore the system should be able to combine knowledge from distinct theories and factual data in order to make an appropriate decision.

2.2 Guha's contribution to context

Following McCarthy, his student Guha[5], extended and elaborated on the concepts that were firstly introduced by McCarthy. Guha's main contribution is in the definition of *focus, perspective, scope* which are logically associated to contexts. He also elaborated on:

1. decontextuallisation,
2. Problem Solving Context (PSC),
3. Problem Structure (PS)

This theory suggests that there are two types of contexts: (1) pre-defined, and (2) created during inference. The latter are contexts created from the collection of theory(ies) and appropriate domain realting to the problem. For this reason, they are called *Problem Solving Contexts*. A *Problem Structure* is a function that assigns to each context a Language and a theory of the world according to context.

McCarthy and Guha were mainly concerned with the knowledge representation aspect of *context*.

Attardi's theory on viewpoints was studied and referenced by many researchers in the area. It constitutes one of the most important attempts to define *context* since the notion of a *view* is interpreted as equivalent to *context*.

2.3 Attardi's notion of context

Attardi[1] used the term *viewpoints* in order to formalize the notion of *context*. A *Viewpoint* is a set of statements and denotes the assumptions of a theory[1]. The statement:

$$in(s, vp)$$

means that *the statement s can be entailed from the viewpoint vp.* Attardi and Simi[1] are mainly concerned with *provability* issues in contexts.

2.4 Chiunchiglia's notion of Context

Some of the most important topics studied by Giunchiglia and colleagues are:

1. Local models and compatibility between contexts,
2. belief contexts for multi-agent theories,
3. A Context-Based Framework for Mental Representation

The above approaches belong to the areas of *knowledge representation*, *formal reasoning, non-monotonic reasoning.*

2.4.1 local models and compatibility between contexts

The notion of *locality* and *compatibility* of contexts was studied by Giunchiglia who was also the first to represent a multi-agent system as a set of contexts. A notion may be understood equally, but applied differently in different situations. For example, a person A may be opposite a person B who is pointing left, i.e. A's right. Given that the simple rules of relativity between the two persons are commonly known, it is easy for each person to configure the direction that B is pointing. However, A thinks that B is pointing to the right whereas B thinks he is pointing to the left. Further, each of the reasoners knows where the other person thinks that B is pointing. It is discussed[4, 3, 2] that in cases where there is full knowledge of the world, it is easy to establish compatibility relations between the contexts of reasoners. However, where knowledge is partial we may only be able to establish a partial compatibility relation.

2.4.2 belief contexts for multi-agent theories

A *belief context* is a set of beliefs under a particular point of view. As each agent has a set of beliefs, then each agent can be represented as a context of beliefs.

2.4.3 A Context-Based Framework for Mental Representation

The context in this case is defined as: *that subset of the complete state of an individual that is used for reasoning about a given goal.* This thesis is based on the assumption that mental contents are organized into small sets of facts. The concepts of *locality* and *compatibility* constitute the core of the theory.

An epistemic approach to the definition of context, was provided by R. Moore. We simply refer to his view, since a thourough review of his theory would need to cover aspects of epistemic reasoning which are beyond the scope of this report. It is classified among the non-monotonic approaches to defining context.

2.5 R. Moore's Context

R. Moore[9] argues in his theory about Autoepistemic reasoning that an exception to a belief doesn't actually cause an inconsistency, but a change in context.

Other examples of areas where *context awareness* is essential are: (1)machine learning, (2)planning, (3)robot navigation, (4)perceptual understanding and communication. In general we can say that context awareness is essential where there is a need to handle information intelligently.

3 Whose context is important to whom, or what?

The above studies of context are useful in knowledge representation, automated theorem proving techniques, design of formal frameworks for reasoning of intelligent agents. McCarthy's, Guha's and colleagues research relates to the way machines use common sense to reason. R. Moore's ideas emphasized the notion of reflection on ones own beliefs and the distinction between the notions of belief update and revision. Giunghiglia's approach is mainly concerned with the way different reasoners can apply context-based reasoning. Their work also relates to belief revision, and multi-agent theories. These theories can also be applied in linguistics and natural language processing:utterances need to be exchanged within the same context to be meaningful.

4 Where can an awareness of context be exploited?

Example areas where *context-awareness* may prove useful, are:

1. **machine learning**
2. **planning**
3. **vision**
4. **robotics**
5. **agents**
6. **argumentation**

5 When is context useful?

Context is useful where it is not possible or feasible to establish guidelines of behavior that cover all possible situations. Some concepts that we find interesting to investigate with regard to context are: **conditionalization, situation, adaptation, semantic meaning, inheritance** and **uncertainty**

5.1 conditionalization

A *context* is usually based on hypotheses, which may be implicit or explicit, upon which assessments are conditioned. Those hypotheses may have a unique correspondence to the context and may even express a form of causal relation. It is also possible to think of a context being created from *counter-factuals*. Possible areas of concern are:

1. whether conditionals can be used to represent context.

2. the type of association between conditionals and context.

3. the role of conditionals in inference.

5.2 situation

The occurence of a particular situation naturally incurs the establishement of a new context: a context constrained by the facts that apply to the situation. The facts of a situation are usually relevant when a reasoner aims to bring about an effect. We adopt McCarthy's[7] notation $C(S)$ to represent the context of a particular situation S. Then, if α be an action in the set of all possible actions A, then

$$(S_1, \alpha, S_2) \text{ implies } C(S_1) \wedge \alpha \Longrightarrow C(S_2).$$

the exact notion of $\Longrightarrow$ needs to be studied. Some of the problems of conditionalization may also be observed here.

5.3 adapdation

A context is useful when we need to have adaptation. This occurs when it is not possible to follow strict guidelines on how to react in each situation. Also, a system needs to be able to reach different solutions in different contexts.

5.4 semantic meaning

The semantic meaning of objects or sentences may differ between contexts, and in many cases a word/sentence obtains its meaning from the context in which it occurs. One example is the use of indexical words. Dialogues are carried out with reference to the utterances or conversation carried so far and some common assumptions made by the participants.

5.5 inheritance

Parent-child type of relations are important in the study of *context awareness* since the inclusion of an object into a class assumes certain constraints in its behaviour.

5.6 uncertainty

Assumptions about the possibility of occurence of an event can vary between situations and contexts. Assumptions made in a context may take the form of prior probabilities.

6 Why are context-aware applications useful?

We think that *context-aware* applications are useful because they have the following characteristics: They are **responsive, adaptive, understanding, situation-dependent, relevant, minimal** and they can **cope with uncertainty**. Below is short analysis of what we mean by each term.

6.1 responsive

Response in the right context, or, with the right answer in each context. It is necessary to:

1. recognise the context in which the solution is searched,
2. determine the context of the solution, and,
3. determine how a solution can vary with context

6.2 adaptive

A *context-aware* system is also adaptable in the sense that whenever a system is adapted, there is a change in some context. We can intrprete the need to adapt a system as a need to create a new context. The opposite does not hold. In addition, we assume that a change may be *internal*, i.e. the reasoner identifies a new interpretation or revised model of the situation. It may also be *external*, i.e. it creates awareness of a change in its behavior.

6.3 understanding

Here we talk about machine and human understanding. *Context-aware* applications resemble human reasoning, but hopefuly with some criteria of *well-formness*. When used interactively, it is possible to create a context of reasoning which is compatible with the information given by the user. The machine can take into consideration the facts and explain inconsistensies relevant to the situation. Further, it can direct the user to the right context of reasoning.

6.4 situation-dependent

Obviouasly, since we argued that each situation can create its own context, then it follows that a *context-aware* application should be situation dependent.

6.5 relevant

Context-aware applications can ensure relevant solutions and reasoning.

6.6 minimal

Minimality is brought in with the sense that context-aware applications integrate only relevant information. Redundant information need not be considered.

6.7 cope with uncertainty

Refers to the ability to reason with partial information and to respond to the facts that are available, or, implied by the situation.

7 How do we implement a generic supporting infrastructure for context-aware applications?

Approaches dealing with this topic are mainly focussed in the following streams of reasoning:

1. to use a meta-level to reason about contexts, or,
2. to extend the language to include statements referring to contexts, or
3. to represent context in terms of other sentences of the language.

We suggest that: (1) a theory of contexts is sustained separately from domain knowledge. (2) we study the feasibility of having automatic recognition and resolution of contexts when utterances are exchanged between intelligent systems. (3) Reasoning can be carried out in many different contexts and (4) inferences from different contexts are integrated meaningfully. Further, we note that since there is no unique architecture for intelligent reasoning, or, integration of information, it is difficult to propose a particular architecture for *context-aware* reasoning.

8 Conclusion

Context-awareness refers to the ability to recognise aspects which are relevant to the solution of problems and focus on them. The more relevant the information is, the better the quality of the assesment is. However, information can take several forms. For example, visual. It can be seen that in cases like this, it is difficult to establish a meaningful model of information. Where should one focus its attention? One may be tempted to investigate whether there is a resemblance in the act of interpreting information of different types. Context-awareness is a challenging topic that falls into many disciplines of research. Each discipline provides its own experience and view. We hope that by combining the different views, we may come up with a good understanding of what a context is, and what we should expect from a *context-aware* application.

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