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Ontology-based approach for context modeling in enterprise applications

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ABSTRACT

Today, enterprise applications provide large amounts of data and finding the right information on time for a given purpose is often a challenge. In these environments, users do not know what information is important, why it is important and finally, how to find this important information. Therefore, an enterprise application has to decide which information is relevant in certain a situation for certain a user. In order to accomplish that, the context of the information must be taken to account. Moreover, this application must be able to capture the context of the application user as well as the overall business context which describes the situation in which information is relevant. In this paper we propose an ontology-based context model which captures the general concepts about user and business context. Also, we discuss the challenges for context reasoning and interpreting and we present a case study to demonstrate the benefits of the developed concepts.

1. Introduction

Over the past years, reliance on enterprise applications for providing and storing information has grown rapidly. These applications are becoming increasingly more complex and are going to be used eventually on any number of devices, from mobile smart phones to industrial computer networks. Thus, to increase their efficiency and electiveness, applications will need to be made aware of the context they are being used in, in order to automatically adapt to it.

Sandkuhl [1] states that in today's information society, information is considered as an important production factor in addition to capital, human resources and material. Furthermore, the task of finding the right information to support a work task, a business decision, or a cooperation process is often very difficult. Some studies revealed that 39% of all business executives spend more than 2 h per day in searching for the right information [2]. This proves that the main challenge is no longer to guarantee the existence of much needed information, but rather to find and provide the right information [1,3].

The motivation for this work lays in the fact that in certain situations not all information provided by an information system is important and relevant to the end user. Modern enterprise information systems provide huge amounts of information and in these large volumes very often the user cannot identify appropriate and important information at the right time. Moreover, in complex business environments users may not be fully aware of the current situation which in turn can negatively influence the decision making process. So, it is very important to provide the appropriate information to the user considering the respective situation. However, even if the user is provided with this information, the problem is not essentially solved. The user also has to understand why the provided information is important which means that he/she has to comprehend the current situation or to be aware of the context in which this situation happened. In this way, the user is able to fully understand the real meaning of the information. Therefore, it has become crucial for enterprise applications to be aware of the context they are being used in.

Nowadays, enterprise applications collect and store various kinds of data and information. This data describes users as well as the various aspects of business. This means that if properly interpreted, this data could be used to describe the overall user and business context. However this is no easy task as context data is subject to constant change and can be highly heterogeneous.

This paper proposes an approach to solve these problems by providing an ontology-based context model and rules for its

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interpretation. This model will classify with the help of OWL-built ontologies the context of the users (the employees of a business who are accessing the system) and the context of the business. The user and business context will allow for an enterprise application to anticipate which information is important and relevant in order to serve it to the appropriate user. Since the solution utilizes contextual information and provides information and services according to it, the proposed approach could thus be characterized as "context-aware".

This paper reviews the notion of context as well as various methods for context modeling and proposes an approach for context modeling in enterprise applications. After the introduction section the formal definitions of context are discussed. The requirements that any context model must meet are presented in Section 2 as well as the review of the context modeling methods with special focus on the ontology based modeling in Section 3. Section 4 gives an overview of the proposed approach for the context interpretation and the context ontology is introduced and presented together with the outstanding features of the approach. Finally, a case study based on the industrial scenario is presented in Section 5.

2. Context definition

The meaning of the term context had an evolution toward a larger acceptance and now the meaning generally accepted is that context is the set of circumstances that frames an event or an object [4]. Context is increasingly being used in various disciplines like psychology, especially since the emergence of situated cognition theories [5], those theories considering cognition in its natural context [6]. However, it is difficult to find a relevant satisfying definition for every discipline. Some approaches emerge in Artificial Intelligence ([4,7]).

In his work on formalization of context, McCarthy [8] pointed out the difficulty in computer science of modeling context because context possesses an infinite dimension. Furthermore, he addresses the difficulty in translating contextual assessment that has been conducted in the psychological or philosophical realm into formal computational logic. Parker et al. [9] emphasize the necessity when considering context to also consider the human ability to analyze the context of a situation and rank the different stimuli of the outside environment. Bazire and Brézillon [4] analyzed a corpus of 166 definitions of context found in a number of domains and came to the conclusion that context can be derived from anything that is significant in a given moment including the environment, an item within that environment, a user, or even an observer [9].

Even though context is a difficult concept to grasp and define, a widely accepted general definition is as follows:

> *Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.* [10]

Another widely accepted definition of context is given by Brézillon and Pomerol and it says that context is:

> *That which constrains something without intervening in it explicitly.* [11]

These definitions outline two different notions related to context: information about the relation of an entity vis-a-vis its situation and using this information to help an application complete its task. However, Zimmerman [12] states that this definition is too formal and universal and missing an important operational part. Indeed, the type of information needed to define the entity-situation relation is not defined in the above definition but is required for any pragmatic approach to context modeling. The authors of [12] propose the following five categories of context information: individuality, activity, location, time and relations.

Considering the origin of the context information, it can be retrieved from internal and/or external sources. Internal context is represented by data and information that comes from the system, such as system state, events that happen etc. On the other hand, external context is represented with information coming from outside the system, such as device type, location etc. Some authors have classified context depending on the way data is captured into three groups: physical context, virtual context and logical context. Physical context is represented with data coming from physical sensors such as GPS devices, light sensors etc. Virtual context is based on information coming from software applications or services. For example the position of the user can be determined by browsing his electronic calendar, emails etc. Finally, logical context is derived from information coming from various information sources. It combines information both from physical and virtual sensors [13].

Although most authors refer to abstract context sources, the mainly used and tested sources currently are physical sensors. Virtual and logical sensors are capable of providing useful context data as well and this will be incorporated in this research [13].

3. Context modeling

As shown in the previous section, context information can be obtained in a wide range of forms. Thus, efficient and effective means of modeling the information are needed. One of the biggest problems in the existing solutions is the variety of the used context models as well as the different ways to find and access the context sources. Every system and framework uses its own format to describe context and its own communications mechanisms to access it. Standardized formats in this domain however are crucial for the enhancement of context-aware systems to shift the focus from the communication between context sources and users to the development of valuable context services.

Before moving on to the state of the art of context modelling, the requirements that these models must meet are given. A context model must meet the following requirements as defined in [14]:

- **Applicability**. A context model should be able to be used for many different applications entered around a single task. This requirement entails that context models must be flexible in the way they can complete a given task, due to the fact that context data is heterogeneous.
- **Information analysis**. Context information, as already stated, can be of many different types, since it is extracted from a multitude of sources. The model must be able to compare the information resulting from different measurements. Furthermore, the model must be able to determine the source of information and how it has previously been processed. This requirement is known as traceability. Finally, acquired data from multiple sources may be incomplete or contradict itself, resulting in the need for methods for resolving such issues.
- **History**. Any context model must provide a means of storing and accessing past information. Indeed past information can be useful to make predictions that may be valuable for present decisions.
- **Inference**. The information acquired from devices such as sensors is only raw data, also known as low-order context. A context model is required to able to apply reasoning on low-order context data in order to obtain high-order context on which to base decisions.