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An Ontology for Spatial Relevant Objects in a Location-aware System: Case Study: A Tourist Guide System

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***Abstract*—**Location-aware computing is a type of pervasive computing that utilizes user's location as a dominant factor for providing urban services and application-related usages. One of the important urban services is navigation instruction for wayfinders in a city especially when the user is a tourist. The services which are presented to the tourists should provide adapted location aware instructions. In order to achieve this goal, the main challenge is to find spatial relevant objects and location-dependent information. The aim of this paper is the development of a reusable location-aware model to handle spatial relevancy parameters in urban location-aware systems. In this way we utilized ontology as an approach which could manage spatial relevancy by defining a generic model. Our contribution is the introduction of an ontological model based on the directed interval algebra principles. Indeed, it is assumed that the basic elements of our ontology are the spatial intervals for the user and his/her related contexts. The relationships between them would model the spatial relevancy parameters. The implementation language for the model is OWLs, a web ontology language. The achieved results show that our proposed location-aware model and the application adaptation strategies provide appropriate services for the user.

***Keywords*—**Spatial relevancy, Context-aware, Ontology, Modeling

I. Introduction

EMERGING pervasive computing technologies support 'anytime, anywhere' computing by decomposing users from devices and applications as entities that perform tasks on behalf of users [7]. To avoid increasing complexity and allow the users to focus on his tasks, applications and services, the system must be aware of its contexts and automatically adapted to its changing situations [9]. Location is an important context, which is changing all the time for a moving context-aware user, in this way representing location-aware services are necessary services for mobile users in a changing urban area. One of the important fields of the application of location-aware systems in a city is a tourist guide system. A tourist which is unfamiliar to an urban area, need a guiding system introducing environment and consequently adapt all his behavior to that situation without an explicit demand from the user when its fundamental factor is location of the user.The realization of the location-aware adaptation of applications requires studying many issues including positioning and its related context detection, context modeling and interpreting, context dissemination and application adaptation to the location [1]. It is proved that utilizing spatial relevancy concept in location-aware systems could enhance the context adaptation based on the location of the user [19]. There are a number of researches in the field of modeling location-aware system for many applications [13, 18].Moreover, the question ''how to model the spatial relevancy in a location-aware system?'' remains without a precise and complete answer. Such an infrastructure requires a common context model that can be shared by all devices and services.In this paper, an ontological approach is proposed to address this problem by proposing a reusable and flexible spatial relevant model for a location-aware system. Our contribution is the introduction of an ontological model based on the directed interval algebra principles. The ontological location-aware model is based on the semantic representation of location and context data, rules and concept ontology. Two spatial directed intervals are considered semantically for the user and context. The relationships between them model the spatial relevancy parameter. By applying the ontology and the semantic web technology, an ontology-based spatial relevancy models is proposed using OWL [23]- an ontology markup language to enable context sharing by explicitly defining contexts in a semantic way.The paper is organized as follows: after reviewing the state of the art in context modeling and location-aware adaptation in Section 2, the related concepts including context-awareness and location-awareness, spatial relevancy and ontology are presented in Section 3.

The proposed ontological model is presented in Section 4. The implementation strategy and architecture of the system are outlined in Section 5. Then the case study is elaborated. Conclusions and highlights of our future work are given in Section 6.

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II. Background

There are a number of researches in the field of urban facility management which have been focused on the concept of context in order to provide appropriate services for citizens over the last decades. Context appears as a fundamental key to enable systems to filter relevant information from what is available, to choose relevant actions from a list of possibilities, or to determine the optimal method of information delivery [22]. Some of these activities are concentrated on modeling the contexts supported by location or location-aware system.

Geake mentioned that one important criterion among other criteria for a successful service is the relevance of the delivered information [8]. Raper et al. claimed that "… understanding the individual 'geospatial relevance' of information will be necessary for location-based services to provide appropriate information [8]." Reichenbacher modeled relevancy parameters and proposed some general rules of thumbs for the assessment of relevancy for geospatial objects that build a kind of hierarchy of relevant objects [19]:

- Nearer objects are more relevant then objects further away.
- Visible objects are more relevant than hidden or invisible objects
- An object or objects attribute is relevant, if it is needed for the successful completion of an activity.
- Objects that are linkable to users' prevalent knowledge are more relevant.

Finally Reichenbache rclaimed that the bases of finding relevant contexts are physical and spatial relationship [19]. Kwon and shin implemented a context-aware system "Location-aware COoperative Query system (Laco)". They modeled spatial relations with metric distance and applied shortest path [13].

Vieira et al. improved a context-sensitive system that use context to provide more relevant services or information to support users performing their tasks. They introduced 'behavior metamodel' to find relevant contexts. The model was related to the dynamic aspects of context manipulation in a domain-independent manner. In the model they consider spatial parameters or locations [27].

The use of ontology in information systems establishment is discussed by Guarino [10]. Strang and Linnhoff-Popien present an investigation of six spatial problem modeling approaches including key-value modeling, markup scheme modeling, graphical modeling (e.g. UML, ER), object oriented modeling, logic-based modeling and ontology-based modeling. According to their analysis that is based on the appropriate requirements, they found that ontology-based modeling is the most promising approach for spatial modeling in mobile computing environments [24].Chaari et al. introduced a comprehensive approach to model and use context for adapting applications in pervasive environments [4]. The context model used ontology representation based on the basic context descriptors. The achieved results showed that their context model and the application adaptation strategies provide promising service architecture.

Jiang and Tan presented an ontology based user model, called user ontology, for providing personalized information service in the Semantic Web [12]. The experimental results, based on the ACM digital library and the Google Directory, support the efficiency of the user ontology approach to provide personalized information services.

III. Context Modeling And Reasoning

In this section, the concept of context-awareness and location-awareness are described. In addition, the spatial relevancy parameter as a main factor in modeling a location-aware system is outlined. The use of ontology and OWL in modeling contexts is also explained.

A. Context-awareness

Earlier works verify that contexts describe situations. Dey and Abowd have confirmed this by defining context as: ''any information that can be used to characterize the situation of an entity. An entity is a person, a place, or a physical or computational object that is considered relevant to the interaction between a user and an application, including the user and application themselves [5].''

A range of characterizations and definitions for context and context-aware systems has been surveyed and analyzed. It can be observed that context-awareness and context-aware systems evolved from location-awareness by generalization. Further concepts that constitute the environment which can be measured are included in the understanding of the context [22].

Exemplarily, several projects that reflect current trends in ubiquitous computing research and in the area of context-awareness have been presented [22]. It can be observed that even if the notion of the context is widened in most research groups, the systems that have actually been implemented rely mostly on location. Location as a prime context is very well understood [15] and context-acquisition devices are available off-the-shelf, at least for outdoor positioning systems.

Furthermore, the value of location as context is obvious. The value of other context information, especially about the environment, is often not clear and measuring them often requires specific hardware. Most of the work on context acquisition is centered on location or shows an opportunistic sensor selection. In mobile location-aware systems, the position is an attribute of the device and implicitly of the user who is carrying the device [22].

Mobile computing can be divided, depending on information access methods, into two categories: (1) conventional mobile computing that does not have the means for obtaining and utilizing user's current location in processing activities and (2) location-aware computing that is capable of obtaining and utilizing user's current location information as one of the essential parameters for providing services and application-related optimization [6, 14].

B. Spatial Relevancy

Saraceviec offers a general definition of the relevance derived from its general qualities [21]:

"Relevance involves an interactive, dynamic establishment of a relation by inference, with intentions towards a context. Relevance may be defined as a criterion reflecting the effectiveness of exchange of information between people (or between people and objects potentially conveying information) in communication relation, all within a context."

Humans are always at a certain position in space. Usually the current position – 'the here' – is the centre of action, perception, and attention. The perception, e.g. what someone feels, hears, and sees, is dependent of the position and the spatial distances to the source of context. This results in the fact that the context that is perceived is strongly dependent on the position where someone is [22].

Moving position is also a human way of selecting an appropriate context for the activity that is performed. An example is walking towards the lights when observing something very closely; the lighting condition – the context – is changed by changing the position. This is a very powerful concept and adapted in many location-aware applications [22].

Humans use space and locality as an efficient tool for structuring the environment and also to support tasks and actions. Spatial arrangements of artifacts are a most natural way for humans to order things. These spatial arrangements play a vital role when interacting with objects. Especially the concept of co-location is powerful and very often used, e.g. the books that are physically close on the shelf are often also similar in content [22].

Situation and context can be seen as phenomena that are related and bounded to a particular place or region. Two of the most widely used aspects of context are place and time. Location information can aid users in different ways. It can cause automatic system behavior at certain places, such as notification on important objects in the environment [25]. The place or region where context information emerges – or that is assigned to this context information – plays an important role, especially in mobile and embedded systems. The place or region must not be seen isolated, it is always an attribute assigned to an identity, a process, a device, a task, an application, or to data. In mobile location-aware systems the position is an attribute of the device and implicitly of the user who is carrying the device.

Collecting data from the environment and acquiring context out of this data is inherently bound to a location. The readings are collected at a particular position and therefore they represent the context for this particular position or the area related to this position. The information is fully relevant at this position. Generally, the relevance of the data declines with the distance from its point of origin [22]. Therefore locality of context is quite important and should be included in the model as one of the basic relevant parameters called "spatial relevancy".

The importance of "spatial relevancy" is proved in location-based and context-aware systems. Modeling this type of relevancy is necessary for context-aware services to provide appropriate information[19]. However, it seems that the incorporation of spatial relevancy in context-aware systems has not been reported in literature.

C. Ontology and OWL

Ontologies are used to study the existence of all kinds of entities, abstract and concrete, that make up the world [26]. The first recorded attempt at a complete ontology of reality is believed to be by Aristotle in 340 BC, in his seminal work 'Categories' [16] later adopted by Plato [2]. This study of explaining reality by breaking it down into concepts, relations and rules has been known as ontology [3]. There is also a domain-specific and user-dependent view on ontology. Sowa defines ontology as the method to extract a catalogue of things or entities (C) that exist in a domain (D) from the perspective of a person who uses a certain language (L) to describe it [26]. As opposed to the realist view, the domain-specific perspective on ontology is the underlying principle for its application in information science and knowledge engineering (KE). One of the earliest definitions for ontology from the KE perspective is that it defines the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary [17]. Guarino and Giaretta have provided a further terminological clarification between the uses of ontology variously as an 'informal conceptual system', a 'formal semantic account', a 'specification of a conceptualisation', a 'representation of a conceptual system via a logical theory', the 'vocabulary used by a logical theory', and a 'specification of a logical theory [11]'.

Ontology is, therefore, the manifestation of a shared understanding of a domain that is agreed between a number of agents, and such agreement facilitates accurate and effective communications of meaning, which in turn leads to other benefits such as interoperability, reuse and sharing [2].

Modeling context using an ontology-based approach allows us to describe contexts semantically in a way which is independent of programming language, underlying operating system or middleware. The main benefit of this model is that it enables formal analysis of domain knowledge, i.e. context reasoning using first-order or temporal logic.

IV. Ontological Model for Spatial Relevancy

The basic concept of our proposed spatial relevancy model is ontology which provides a vocabulary for representing knowledge about different contexts and for describing specific situations based on the user and domain contexts. The basic model has the form of *spatial-relevancy (user, contexts)* in which:

- *Spatial-relevancy:* spatial relationships between the user and contexts, e.g. user A meets context B.
- *User:* a moving user who travels with a car, in our case study he is a tourist.

- *Contexts:* objects or places which are related with the user semantically, e.g. historical places for a tourist.

In the model, we define two main elements including context and user. Every context has an influence interval along a path. So applying directed spatial intervals for the users and contexts and defining the possible spatial relationships between them could model the spatial relevancy. Based on the Renz's (2001) spatial odyssey of interval algebra, these relations are overlap (2), meet (2), Contain & inside (2), Covered by (2), Covers (2), disjoin (2) and equal (1). Of course Renz explained 26 spatial relationships between directed intervals, however as we consider the intervals of the contexts non-directed, so we have 13 relations (Table 1) [20].

TABLE I
THE 13 BASIC RELATIONS FOR SPATIAL RELEVANCY MODEL

Directed Interval's Base Relations	Symbol	Pictorial Example
x behind = y	b=	-x-> -y->
x behind #y	b#	<-x- -y->
x meet from behind =y	mb=	--x--> --y-->
x meet from behind# y	mb#	<--x-- --y-->
x overlaps from behind =y	ob=	---x---> ---y--->
x overlaps from behind #y	ob #	<---x--- ---y--->
x contained-in = y	c=	--x--> ---y--->
x contained-in # y	c#	<--x-- ---y--->
x contained-in the back of = y	cb=	--x--> ---y--->
x contained- in the back of # y	cb#	<--x-- ---y---
x contained-in-the-front-of # y	cf=	--x--> ---y--->
x contained-in-the-front-of # y	cf#	<--x-- ---y--->
x equals = y	eq=	---x--->; ---y--->

Context information has a great variety and context-aware systems will be used in many different applications. We adopt a two-layer hierarchical approach for designing our context ontology model (Figure1). Our context ontologies are divided into the common upper ontology for the general concepts and the domain-specific ontologies which apply to different sub domains.The generalized ontology captures general contexts for all pervasive computing domains. The generalized ontology is fixed once defined and will be shared among different domains. The domain-specific ontology is a collection of low-level ontologies which define the details of general concepts and their properties in each sub-domain such as tourist domain.

V. CASE STUDY

We implemented the ontological location-aware model in a prototype system which its main task is guiding a tourist in an urban area. The study area is in a part of Tehran, the capital of Iran. We selected Tehran's District 2 as it has many points of interests such as museum, down towns, sport centers and a fantastic mountain.

The scenario of the research is as followers:

- User will be guided from the hotel or where she/he is settled.
- This point is the origin of the tourist movement, and otherwise she/he should introduce her/his place to the system.
- With the information of the origin, the user selects her/his point of interest (destination) based on her/his preferences (we introduced the characteristics of the places textually).
- The system determines the optimum route between the origin and destination (the optimum parameter is selected by the user, for example the least time or the shortest path).
- During the movement, the tourist can be provided with location information of other points of interests which placed on the route of the user (the characteristics of the places are shown on the user screen, too).
- Keeping track of locations of the services, the tourist can get an overview of the place where points of interest are located. Also the location-aware system could direct him/her when he/she is near such a spot.

Based on the ontological location-aware model, we designed the architecture (Fig. 2) which aims to provide an efficient infrastructure support for building location-aware services in pervasive computing environments.

It consists of the three main layers: Context-sensing layer, context-middleware layer and context-application layer. Each layer evolves sub-components which act as independent service components as described below:

Context-sensing layer: This layer senses the related context which is the location of the user. Location could be sensed by an external sensor like GPS or entered by the user of the system descriptively.

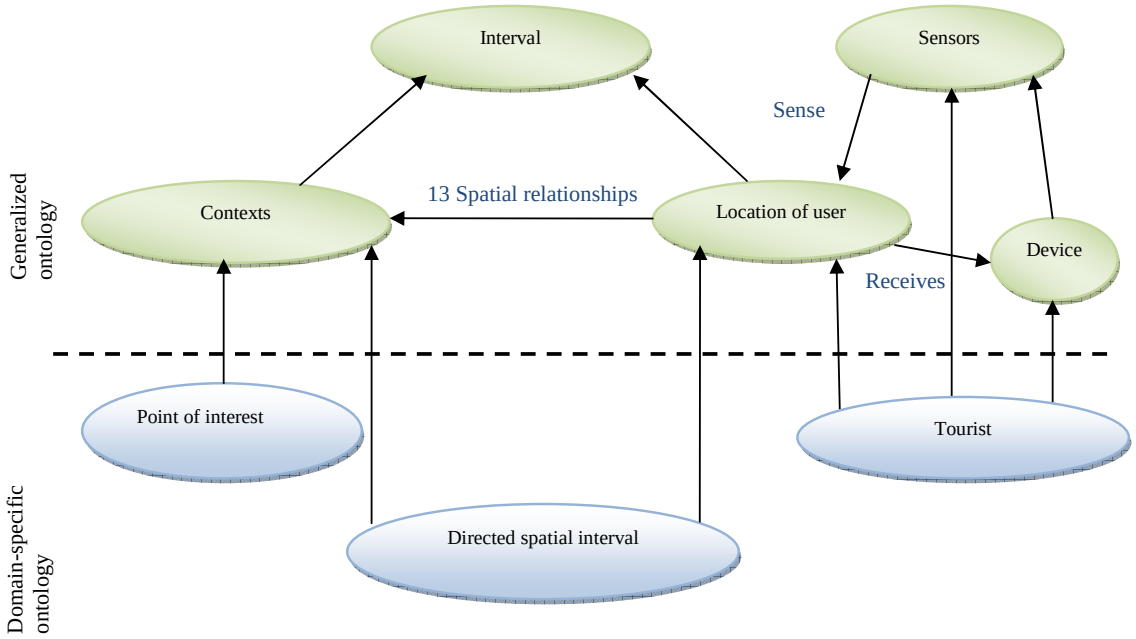

Fig. 1 Ontology of the spatial relevancy model

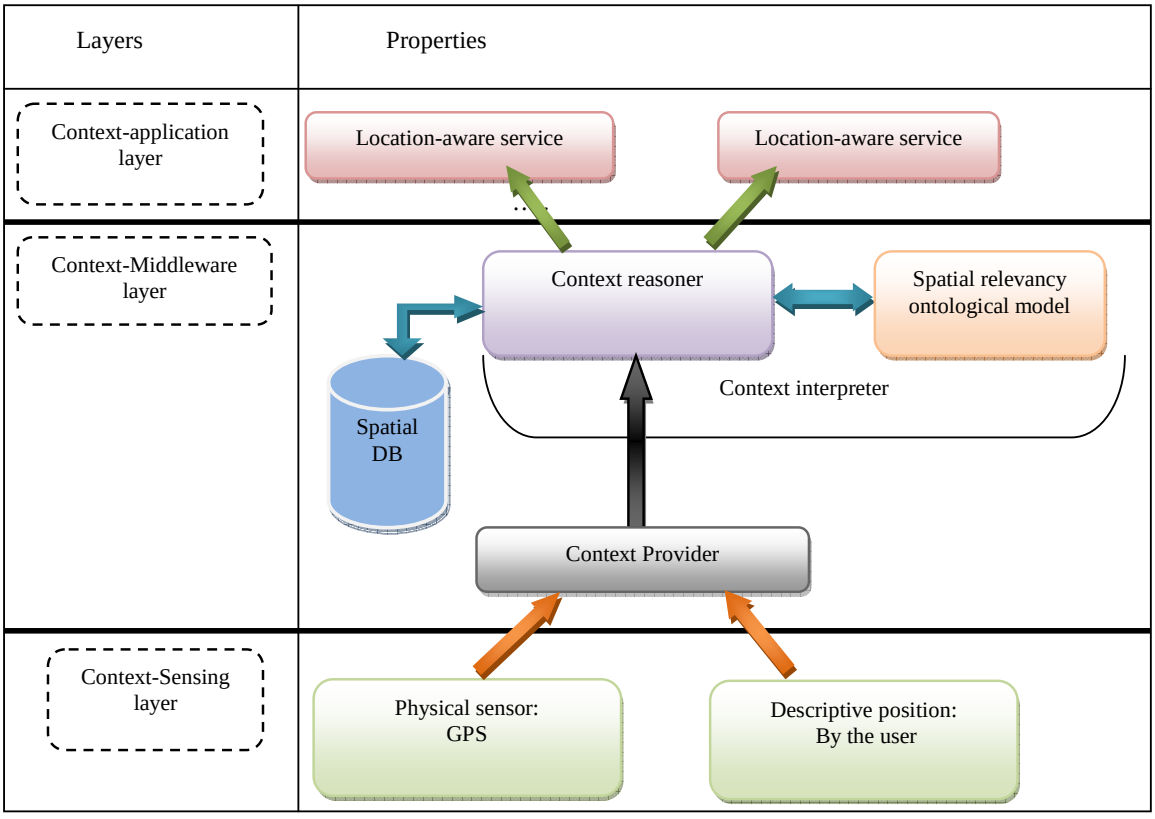

Fig. 2. The architecture of the system

*Context-middleware layer:*This layer consists of three components:

- *Context provider*. They abstract useful contexts from heterogeneous sources (that are location of the user) which are achieved by the external sensor (GPS) or entered by the user.
- *Context interpreter*. It provides logic reasoning services to process context information. This part receives the related spatial data, and then according to the spatial relevancy ontological model and the reasoning engine sends the appropriate location-aware services to the user. Indeed, the spatial relevancy model detects the spatially related contexts for the user.
- *Context database.* It stores related context information (geo-referenced generalized map and its attribute) and past contexts for a sub-domain

Context-application layer: It refers to the location-aware services which are provided by the system. Indeed it is the output of the algorithm. It makes \\\\\ use of different levels of context-aware services which are adapted according to the current location. So services change based on the dynamic nature of the user and the environment.

We have implemented the algorithm in Vb.net and developed a prototype in a tourist guiding system
which consists of mobile phone and GPS. In our model, contexts are described by ontologies written in OWL. OWL, a key to the Semantic Web, is a web ontology language proposed by W3C's Web Ontology Working Group. Fig. 3 shows a partial context ontology written in OWL.

```
<owl:Class rdf:ID="Tourist">
    <rdf:SubclassOf rdf:resource="#location of user "/>
</owl:Class>

<user: Tourist rdf:ID="Reza">
    <rdfs:meet  rdf:resource="#Niavaran park "/>
</ user: Tourist >
....
</ rdf: RDF >
```

Fig. 3 A partial context ontology written in OWL

VI. Verification of the Model

In this section, the proposed ontological model for spatial relevancy is verified and its ability to facilitate the development of context-aware systems is shown. The goal of this verification is to demonstrate the advantages that the proposed model provides in the development of a context-aware system. Our metric for verifying the proposed model is based on the number of spatially related contexts which should be detected by the model and its accuracy.

We evaluated the model in a directed urban network for a user with different origins and destinations in our case study area. Then we compared the achieved results and predicted outputs. We consider 30 different routes for the tourists. In each route we took a number of contexts as control points have been considered and the system is run while the user moves. Then the numbers of detected contexts compared with the control contexts are counted. Fig. 4 depicts the difference of the two diagrams of the detected contexts and the control contexts visually.

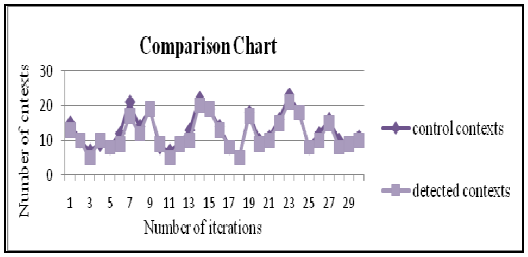

Fig. 4 Diagram of the comparison between the control objects and detected contexts

This comparison proved that the proposed approach could effectively model spatial relevancy parameter in location-aware system.

VII. Conclusions

In this article, we have presented a formal context model based on OWL to represent, manipulate and access context information. Based on our ontological location-aware model, an architecture has been designed for the system to support the development of location-aware services. The prototype system and evaluation results demonstrate a reasonable performance and our model is able to meet the requirements of context-aware systems concerning limited memory and CPU resources in pervasive computing environments. The implementation of the location-aware system in an urban area is carried out based on our ontological model for a moving tourist. On the other hand, our model is reusable in other fields like navigation systems or police officer guiding services. The experimented results show that the proposed approach would effectively model and could accurately detect spatial relevant contexts.

As a continuation to this work, we plan to work on modeling time as a context and presenting a spatio-temporal model for detecting spatio-temporal relevant context.

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