Modeling Spatial Relevancy in Context-Aware Systems Using Fuzzy Intervals

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Abstract

With an ongoing variety of pervasive computing devices integrated in our environment and an increasing mobility of users, it is necessary for mobile systems and services to be context-aware. Introducing relevant contexts to the user is the main properties of context-aware systems especially spatial relevant contexts. Most often as situations change gradually, there is no sharp boundary about how far one can see some relevant objects. It seems that contexts do not have crisp borders where they are true on one side but false on the other side. On the other hand, every context and mobile user has an influence interval in an urban network. So applying fuzzy spatial inervals for contexts and mobile users and defining their spatial relationships could effectively model spatial relevancy parameter. The main contribution of this paper is introducing fuzzy interval algebra for modeling spatial relevancy in context-aware systems. The proposed algorithm is implemented in a context-aware tourist guide system. The experimental results showed that the algorithm could accurately detect the spatial contexts.

Keywords: Fuzzy Spatial Interval; Context-aware; Interval Algebra; Tourist.

1 Introduction

Context-aware systems are computer systems that use context to provide more relevant services or information to support users performing their tasks, where context is any information that can be used to characterize the situation in which something exists or occurs (Vieira et al., 2010). The major challenge of the context-aware systems is to find an acceptable degree of information reduction to the relevant ones (Reichenbacher, 2005). Relevancy is a parameter which depends on the contexts supported by the system. Brown (1996) described that "context awareness", is a term that describes the ability of the computer to sense and act upon information about its environment, such as location, time or user identity”. Because of the importance of location in fieldwork applications, the hand-held computers used are normally connected to a GPS receiver.

Reichenbacher (2005) modeled relevancy parameters and proposed some general rules of thumb for the assessment of relevancy that build a kind of hierarchy of relevant geospatial objects. He claimed that the bases of finding relevant contexts are physical and spatial relationship. Kwon and shin (2007) implemented a context-aware system “Location-aware COoperative Query system (Laco)”. They modeled the spatial relations with metric distance and applied shortest path.

Review of the related researches proved that spatial relationship between the user and the contexts is a dominant factor for finding relevant objects in context-aware systems. However, it seems that more research to explore qualitative and quantitative spatial relevancy modeling is still needed.

The objective of this paper is to provide relevant information to the right situation for mobile users. We aim to model spatial relevancy parameters via spatial relationships between the user and his/her contexts. The main contribution of this paper is using fuzzy spatial interval algebra to model spatial relevancy in context-ware systems. It is assumed that the locations of users and the related contexts have a fuzzy spatial interval. A fuzzy spatial interval is a spatial interval which is not crisp and follows a fuzzy membership function. The spatial relationships between them model the spatial relevancy in the algorithm. The model is implemented in a tourist guide system scenario. The study area is a part of Tehran, capital of Iran.

2 Background

This section, briefly explains the concept of context-awareness and spatial relevancy. Then it is concentrated on the fuzzy interval algebra and its components.

2.1 Context-awareness and Spatial Relevancy

According to Dey's definition, 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. Also a system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task (Dey, 2001 and Saracevic, 1996). 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 (Hong et al., 2009; Chedrawy and Abidi, 2006), or to determine the optimal method of information delivery (Decouchant et al., 2009; Pan et al., 2007).

Saraceviec offers a general definition of relevance derived from its general qualities: “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” (Saraceviec, 1996, p.205).

Collecting data and acquiring context out of this data is inherently bound to a location. The information is fully relevant at this position. Generally, the relevance of the data declines with the distance from its point of origin (Schmidt, 2002). As seen from these observations locality of context is quite important and should therefore be included in the model as one of the basic relevant parameters which is called "spatial relevancy". Modeling this type of relevancy is necessary for context-aware services to provide appropriate information (Reichenbacher, 2005).

2.2 Fuzzy Spatial Relations in Context-aware Systems

It seems that contexts do not have crisp borders where they are true on one side but false on the other side. This fading, or fuzziness, is related to the relevance of the context. In fuzzy sets the main idea is that the membership of a component to a set is not just binary. It is rather fuzzy – meaning that an element has a degree of membership to a set (Schmidt, 2002).

The vagueness of the boarder of context is stemmed from the movement of the user, so by modeling the position of user with fuzzy spatial interval we could model spatial relevancy in an effective way. A fuzzy spatial interval is a spatial interval which is not crisp and follows a fuzzy membership function. The fuzziness of the spatial interval of the user has some characteristics including the following ones:

1) The most spatial relevancy is at the center of spatial interval which is the position of user called origin. The membership degree of origin is “1”.
2) With increasing of distance from the origin, vagueness is increased and membership degree is decreased tending to “0”.

Regarding these matters trapezoidal membership function is selected in this paper.

3) However, regarding the movement of the user with the car, we could specify the certain interval (the part of interval with membership degree equal to “1”) rather than origin. This interval is determined by the velocity of movement. As the velocity increases, the distance of the interval increases.

Figure 1 illustrates the vagueness of the spatial interval of the user in a three-dimensional model in all directions. Trapezoidal function is used whose argument is the distance between the point of origin of the context value and any other point.

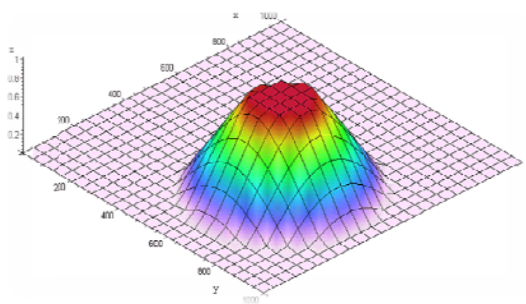

Figure 1: A three-dimensional model of spatial interval of the user in all directions

3 The Proposed Method

In the model, we define two main elements including the context and user. The user and context have an influence interval along a path. So applying spatial intervals for the users and contexts and defining the possible spatial relationships between them could model the spatial relevancy. As the user is moving along a road, a crisp spatial interval could not be defined for him/her. So a fuzzy spatial interval is assumed for the user. Fuzzy membership function of this interval is shown in Figure 2. The relationships between the spatial interval of the context and fuzzy spatial interval of the user model the spatial relevancy between them. If the membership degree of the fuzzy interval is equal to "1", no vagueness exists in spatial relationships. Regarding to our implementation study area which is an urban space with the semi-congested traffic, the common velocity of the moving user in the main streets is supposed to be 60km/h, in this research, During 3 seconds, 50m distance is considered for the domain of user with membership degree of "1".

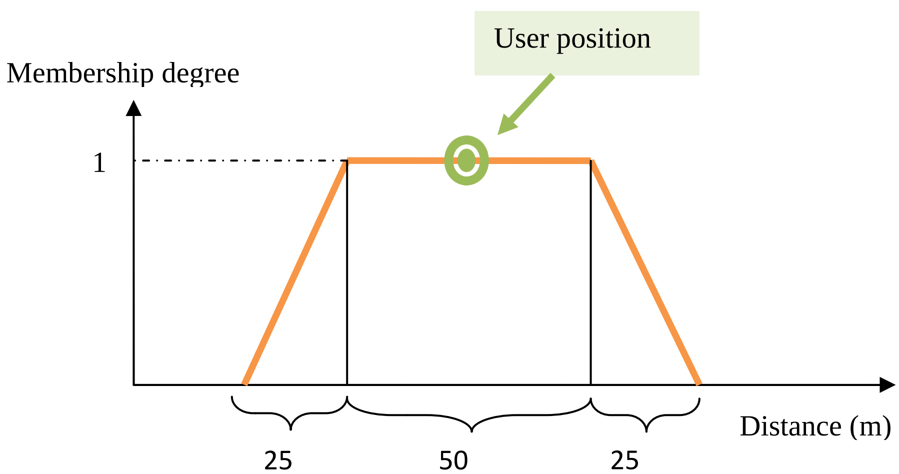

Figure 2: Fuzzy spatial interval

To model spatial relationship between the fuzzy spatial interval of the user and the spatial interval of the context, we applied Renz's (2001) spatial odyssey of interval algebra to define the spatial relationships. These relations are overlap (2), meet (2), Contain and inside (2), Covered by (2), Covers (2), disjoin (2) and equal (1). Renz (2001) explained 26 spatial relationships between the directed intervals, however as we consider the intervals of the contexts non-directed, we are left with 13 relations (Table 1).

Table 1. The 13 basic relations for spatial relevancy model

Fuzzy Spatial Interval's Base Relations	Symbol
x behind = y	b=
x behind #y	b#
x meet from behind =y	mb=
x meet from behind# y	mb#
x overlaps from behind =y	ob=
x overlaps from behind #y	ob #
x contained-in = y	c=
x contained-in # y	c#
x contained-in the back of = y	cb=
x contained- in the back of # y	cb#
x contained-in-the-front-of # y	cf=
x contained-in-the-front-of # y	cf#
x equals = y	eq=

4 Case Study

We implemented the algorithm in Vb.net and developed a prototype in a tourist guiding system which consists of a mobile phone and GPS. The study area is in a part of Tehran.

The model is evaluated in a directed urban network for a user with different origins and destinations in the study area. Then the achieved results and predicted outputs are compared. 20 different routes for the tourists are considered. In each route a number of contexts have been considered as control points and the system is run while the user moves. Then the numbers of detected contexts compared with the control contexts are counted. Figure 3 depicts the detected contexts and control contexts. This comparison proved that the proposed approach could effectively model spatial relevancy parameters in the location-aware system.

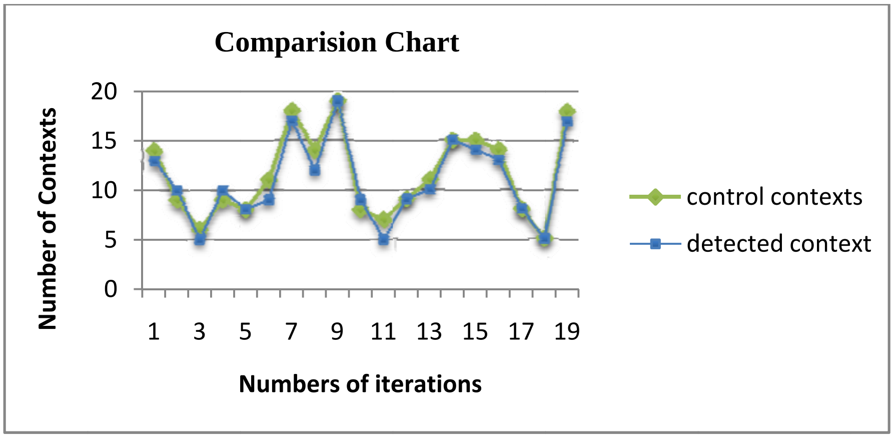

Figure 3. Diagram of the comparison between the control objects and detected contexts

Also we use the statistic indices for specifying the accuracy of the system. We compared the value of the achieved RMSE with the equivalent valid confidence level in 95% and 99% confidence levels. . In other words, the value of RMSE which is equal to 1.38 is smaller than the value of errors at 99% confidence level (1.4) and 95% confidence level (1.6). So our statistics demonstrates that the proposed approach could effectively model spatial relevancy parameter in the context-aware system.

5 Conclusions

A fuzzy context model for spatial relevancy parameters in context-aware system has been proposed in this paper. Based on the proposed model, a fuzzy spatial interval is defined for the user and a spatial interval for the context are determined. The prototype system and evaluation results verified the performance. The 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 context-aware system in an urban area is carried out based on the fuzzy model for a moving tourist. The experimental results show that the proposed approach would effectively 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 contexts.

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