Research on Semantic Location Models for Indoor Location-Based Services

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Abstract. Semantic location model realizes more intelligent and adaptive indoor Location Based Services (LBSs). It is becoming a pervasive data model for defining and managing location information. Employing hybrid semantic methods and theories could solve new changes in indoor LBSs. In this paper, we analyze some typical semantic location models based on mathematic and ontology methods. Meanwhile, from the conceptual modeling for indoor space, we extract the semantics of related location information in the multilayered location model and depict their significance for indoor LBSs. Finally, we point out the development direction of semantic location models for indoor space LBSs.

Keyword: semantic location model, context-aware, mathematic, ontology, multilayered, ubiquitous computing

1 Introduction

Location model plays an important role in LBSs and provides a range of meaningful representations about topological, geometric, direction and location information which are relevant to landmarks and objects[1,2]. It is used to represent and manage location knowledge (like locations, spatial relationships).

Indoor space is becoming the main scenes for indoor LBSs in ubiquitous computing. However, information of indoor space applications has lagged behind outdoor space applications using GPS and GIS technologies[3]. Indoor LBSs need not only fundamental geo-information, but also special location information interacted with users and surroundings to understand physical world. The simple location models, like geometric and symbolic location models[1], couldn't satisfy these changes. Adding semantic information into location models makes information no longer isolated, which combines different aspects of location information for indoor LBSs[4,5]. Consequently, researchers have investigated different modeling methods to design novel semantic location models by some formalized descriptions or programmatic frameworks to adapt to these changes. A reasonable semantic location model could provide valuable location information and reduce complexity of location information management. The existence of well-designed semantic location models ease the development and deployment about location applications.

Existing methods to build semantic location models for indoor space consider many special aspects of concrete applications. The purpose of this paper is to show the state-of-the-art in modeling indoor semantic location models and analyzing the semantics in them. We discuss modeling methods, show lessons learned from current semantic location models and summarize the types of semantic information in the multilayered location model.

The remainder of the paper is organized as follows: Section 2 shows the semantic location models based on mathematic methods. Section 3 shows the semantic location models based on ontology and their functions. Section 4 describes semantic information in the layers/subspace layers of conceptual existing multilayered location model. It also analyzes appropriate semantic information that takes into account the requirements of indoor LBSs. The paper ends with the future development of the multilayered semantic location model in section 5.

2 Semantic Location Models Based on Mathematic Methods

In indoor LBSs, the location models based on mathematic methods could cope with complex spatial problems, like indoor space decomposition, indoor positioning and navigation. The mathematic theories, such as algebra, set theory and graph theory, could be used to solve these challenges for indoor LBSs[6-11]. These theories could be integrated into a programmatic framework by algorithms. No other than, the semantic location models based on mathematic methods finally combine both these theories and the programmatic framework.

There are two typical models, that is, topology-based semantic location model[9] and location-exit semantic location model[12], which are applied into indoor navigation services.

In location-exit semantic location model[12], it uses graph theory and hierarchy structure to improve some navigation algorithms. The concepts of location and exit are the so-called semantic locations[12]. These semantic locations maintain topology relationships and distances between entities, which define some semantic topological relationship, like reachable semantic relation, distance semantic relation[12]. At last, these semantic relations are used into the special algorithms.

On the base of [12], the topology-based semantic location model uses algebraic topology to describe potential semantic information, which are semantic relationship and semantic distance[9]. The semantic relationships express n-ary relationships to describe connective strength and connective length. The semantic distances capture both indoor structure information and real distance information for the nearest neighbor queries between entities. These enhance semantic information of relationships between more than two entities for indoor LBSs.

The majority of these methods solve semantic extension through algorithms for indoor navigation applications, but the semantic ignores interaction with real users. At last, we compare the two models from algorithms which combine the semantic characters and concrete applications.(see Table1).

Table 1. comparison of the two semantic location models based on mathematic methods

name of model	semantic characters	applications	typical algorithms
location-exit semantic location model[12]	semantic topological semantic distances	shortest path query nearest neighbor search	find the shortest path in graph extract CEH from exit hierarchy
topology-based semantic location model[9]	semantic relationship semantic distance	position query nearest neighbor query range query, navigation	computing connective strength computing connective length computing the importance of exits

3 Semantic Location Model Based on Ontology

General speaking, in ubiquitous computing, context expresses a state of entities, like users and interactive objects with users, which could reflect some spatial/location information associated with entities around our daily life. The ontology-oriented modeling approach is a semantic way of organizing these context, which realizes context knowledge sharing and improves advanced reasoning capabilities[13,14]. At last, the whole infrastructure could be combined into semantic location models by hybrid semantic technologies.

In ontology-based semantic location models, context information takes into account relevant location information and is organized by ontologies. We would show some typical semantic location models used ontology engineering methods.

In LOC8 framework[15,16], context information is fused into location model. The whole framework contains three models, named context model, sensing model and space model. They are expressed by ontologies and provide API to describe and apply context information into the LBSs[16]. In particularly, these ontology models could combine rules based on points and regions to infer location information from abstract context level. At last, the framework provides programmatic interfaces for LBSs.

Smart hospital project presents a semantic model, mechanisms and a service to locate mobile entities[17]. There are physical location, semantic location and atomic location in its semantic location model[17]. Atomic locations are the link between physical locations and semantic locations, which is based on the best granularity from the positioning techniques in the current area. In this project, the ontologies and the defined SWRL rules are used to infer knowledge from sensing context and insure the consistency of the whole system[17].

However, maintaining ontology consistency should be paid more attention to the dynamic indoor LBSs. Sharing knowledge also generates some information security problems. So, it should be considered from both developers and users. We also show the comparison between the two models from usage of ontology and some rules for location applications in Table2.

Table 2. comparison of the two semantic location models based on ontology

name of model	usage of ontology	the rules
LOC8 framework[15,16]	space model ontology context model ontology sensing model ontology	spatial relationships rules
Smart hospital project[17]	semantic locations ontology physical locations ontology	sensing areas rules

4 The Multilayered Semantic Location Model

Recently development in the field of location models have given a rise to an interest in the multilayered location model, which is a conceptual framework[18,19]. This model implicitly embodies physical space and cyber space fusion theories. We focus on semantic information in the multilayered location model and analyze the semantics from static information and dynamic information in this conceptual location model.

4.1 Structure of the Multilayered Location Model

The multilayered location model is constituted by three main layers named physical space layer, logical space layer and additional space layer[18,19].

The physical space layer could deeply be divided into some subspaces according to physical surroundings and space relationships, like topographic space layer, topographic subspace layer, sensor space layer. The logical space layer is based on logical conditions or semantic conditions, like accessibility condition, safe condition. The additional space layer has a fine scalability for model expansion, which is added by different context.

4.2 Semantic Information in the Multilayered Location Model

In the multilayered location model for indoor LBSs, semantic information could commendably improve its visualization ability and analysis ability to realize links between different layers/subspace layers.

According to the characteristics of spatio-temporal, semantic information in the multilayered location model is divided into static information and dynamic information, and both of them are relevant to location information. The static information commonly describes the inherent features and functionalities about entities, which would not change with spatio-temporal changes. On the contrary, the

dynamic information represents actions, states, roles, processes and strategies about entities, which would cope with spatio-temporal change. The Fig.1 shows some clear meanings of these semantic information in the multilayered location model. In Fig.1, A contains some relative static topographic information since the whole structure of rooms would not change. The sensing areas in B may change with condition of the WiFi APs(Access Points). The route of C is formulated by the characteristics of the common pedestrians. The D is constructed according to the special additional conditions, like happening fire.

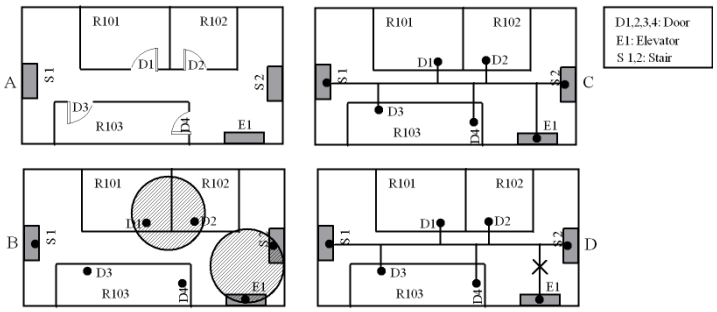

Fig. 1. subspace layers of the multilayer semantic location model.

5 Conclusion

This paper presents different semantic location models. Existing location models for indoor space differ in theories, design, structure and techniques. Analyzing each semantic location model could find different semantic requirements and capture high-level location knowledge about LBSs. The multilayered semantic location model contains semantic information integrated various context information around ubiquitous computing environment, which is about location, topology relationships and distances. Those information are acquired from some positioning sensors and reasoning rules to express the states of entities and provide services for indoor LBSs.

In our future work, the conceptual multilayered semantic location model would be realized by adopting these mathematic algorithms and ontology expression to display semantic functions for indoor LBSs in ubiquitous computing, like position queries, navigation, nearest neighbor queries, range queries.

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