Location and Its Semantics in Location-Based Services

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Abstract  Starting with a simple presentation of location determination techniques, physical location and geographic location as two common kinds of location description methods are discussed. The semantic location concept is then introduced and a correction is given, which especially emphasizes that location property is an important part of semantic location. By analyzing the connotation and extension of every geographic location, what should be contained in a location property is determined. Using a hierarchical model, the relations and associations among locations are clearly described. To realize a formalized description of semantic location, an ontology technique that can adequately describe semantic information of location is used. Organized by ontology web language, a location ontology model allows semantic location to be read and processed by computer. The location ontology model realizes the knowledge description of location information and establishes an important foundation to personalized preference services in location based services.

Keywords  personalized preference services; location; semantics; ontology

CLC number  P208

Introduction

Location-based services (LBS) is an integrated product that has emerged with the development of mobile computing, wireless radio positioning, geo-spatial information processing and other technologies. It runs in a mobile wireless network environment (sometimes it also serves fixed users) and provides value-added information services based on user location. Currently, mobile computing technology has upgraded from offline work to mobile multimedia and is rapidly developing into context-aware computing. Its aim is to realize personalized preference services[1] – a goal that is now an important trend of LBS.

Technologies, services and end-users make up of the three main elements of LBS. Furthermore, user-centered adaptive personalized preference services is seen as an important feature of future LBS[2]. Adaptivity means that the service adapts to the end-user’s preferences and device limitations to provide the best possible service. The more relevant parameters the service takes into account, the better it is able to adapt. In service terms, adaptivity means changing appearance based on the user’s current situation and intentions and device capabilities. For the end user, adaptivity means personalized service based on his preferences and use context. From the developer’s view, the question is how to implement adaptivity in an economically feasible way. All in all, adaptivity is a way to make all services better.

To realize user-centered adaptive personalized...
preference services, the user’s location is the basic information for all value-added services. Therefore, it has always been simply processed. Most LBS systems only use the coordinate value and never consider semantic information, i.e., services have little consideration for the user’s context.

In this paper, we build a new method to describe the user’s location information from its properties and relationships. It contains not only numeric coordinates, but also text. This information is organized by ontology technology with ontology web language (OWL) grammar because the location ontology information should be read and processed by machine in the following services oriented computing. At the end of this paper, an example is given to explain how to use location ontology to build an intelligent volume control service.

The rest of the paper is organized as follows. Section 1 reviews recent research progress on location information process. In Section 2, the technologies of location acquisition are introduced, while Section 3 presents two general describing methods of location. The concept of semantic location is detailed in Section 4. Section 5 discusses how to build location ontology, Section 6 gives an example and Section 7 is the conclusion.

1 Related work

Just as its name implies, location is the most important information in LBS. As the output of positioning platforms, how to describe the location information has been discussed broadly.

Jörg Roth has devoted his study to the construction of a flexible positioning platform for LBS[3] that can provide a semantic location information service. He sees semantic location as a location name with its relationships to nearby locations. He borrows a hierarchical location model to describe the location relationships, but takes little consideration into how the semantic information is used.

Peter Ibach and Matthias Horbank bring forward interoperability on location semantics from the availability of an LBS view[4]. They use service oriented computing to build services and dynamically organize service when the service is required. In their paper, the location semantic information is described by resource description framework (RDF). Therefore, they do not discuss what semantic location is and what information should be contained in RDF.

Location interoperability forum (LIF) has published a standard on mobile positioning of mobile location protocol specification[5]. This specification uses extensible markup language (XML) as its basic language for denoting location information. Its location information is a numerical coordinate and place name without any semantic information.

2 Positioning technology

Location is the most important and basic information in LBS. The general acquiring technology can be classified as stand-alone positioning, satellite-based positioning and station-based positioning. Hybrid positioning technology has been widely used following its rapid development.

Stand-alone positioning is when a terminal can get its location with moving information and does not depend on other outside infrastructure. A typical stand-alone positioning is dead reckoning. Global positioning system (GPS) is a typical satellite-based positioning technology. It uses the observation of a navigation satellite to compute a user’s geodetic coordinates. Station-based positioning technology is newly developed in mobile communication networks. To ensure good precision location, cell-ID, time of arrival (TOA), time difference of arrival (TDOA) and other wireless radio positioning technologies have been developed. Because of poor indoor positioning conditions, wave local area network (WLAN) and Bluetooth have been used in ad-hoc networks to establish terminal location.

To avoid the limitations of available area and precision of a single technology, assisted-GPS (A-GPS) technology can use network base station information and mobile terminal GPS information for pseudo-range difference. It has better positioning precision than mobile communication network positioning and shorter positioning time than a single GPS. The most important advantage is that it has more available applied area and can be used indoors and in dense building areas.
3 Location description methods

There are two general methods to describe location information: physical location and geographic location.

3.1 Physical location

Physical location is a numeric description in a certain reference coordinate framework of a point on the earth’s surface. It can be denoted by \( n \) dimensions as

\[
\text{Location} = (X_1, X_2, \ldots, X_i, rs)
\]

where \( X_1, X_2, \ldots, X_i \) are the components, the dimension number is determined by two factors – a specific requirement and the capability of the reference coordinate framework. \( rs \) is the reference coordinate system for the coordinate definition that gives the effective domain.

As the output of positioning technology, physical location is always used to denote location information. A geodetic coordinate is the most common physical location in an LBS.

Under numerous conditions, the location provider and application have a stipulation for a certain reference coordinate system, such as the world geodetic system 1984 (WGS 84). Consequently, \( rs \) is always omitted.

Sometimes physical location can be denoted by a flat rectangular coordinate for big scale map description. WLAN will use a local coordinate system for physical location.

3.2 Geographic location

Geographic location is the text description of an area in a special confine on the earth’s surface. It can be denoted by two dimensions as:

\[
\text{Location} = (\text{Name, Area})
\]

where Name is the text description of location information, or the name of a location; Area is the name confine, it refers to the condition where this Name can be used without error.

Using this concept, we add Area dimension as a confine because Name may repeat over a wide area. Otherwise, this confine can be stipulated by the location provider and application. Thus, Area can be omitted when there is no Name difference.

There are two common geographic locations; one is the name of a point or an area on the earth’s surface in regional terms and the other is the name of physiognomy or object. Obviously, these two Name denotations will not appear in repetition and thus Area can be omitted.

4 Semantic location

Physical location and geographic location can give some semantic information of location to a certain extent. Jörg Roth’s semantic location contains the location relationships. But both cannot express the semantic location completely. Because whether physical location or geographic location cannot express the location property, we think that semantic location is a three dimensional group with geographic location, location property and relationships as

\[
\text{Location} = (\text{Name, \{Properties\}, \{Neighbours\}})
\]

where Name is geographic location; \{Properties\} is a collection of a series of property elements and property values; and \{Neighbours\} is a collection of nearby locations and its relationship with current location.

4.1 Location property

When we define a semantic location, the key word (i.e., geographic location) is a conceptual noun. All of these words contain some connotation and extension. In this paper, we discuss location property and aim to provide an appropriate service at an opportune time and in the proper LBS context.

Every word identifying a location is a concept that has built a collection of related things and rules in the human brain. When we talk about it, we can deduce something about this concept. We can deduce the location concept in two ways. One is location concept connotation, which refers to the basic character of a location concept such as colour, size, and components. The other is location concept extension. It is the application of location and some rules that promoted this application.

Different location concepts have different connotations and extensions, and therefore different properties. There is no universal property list that can ex-
press all kinds of location concepts. The property list must be defined by its applications.

4.2 Location relationship

The Earth’s surface is composed of infinite locations, all of which have specific relationships. When we construct semantic location, to eliminate the effect caused by the location area confine, a hierarchical model is introduced[3] (Fig.1).

This hierarchical model is composed of some domains, each of which is composed of some child-domain. The domain and child-domain construct the hierarchical relationship. Either domain or child-domain refers to a certain location area. The semantic location just describes a location area. Strictly, physical location is a location area because a point coordinate value can be converted into a circinal area by adding its precision information. Thus, a domain model can adequately describe location information.

In building the domain model, we use the domain name system (DNS) on the Internet. In LBS, there are two common DNS.

The first DNS is the regionalism domain system, which is marked white in Fig.1. The root domain name is nation cn(China). The first hierarchy child-domain name is province ha(Henan) and the second hierarchy child-domain name is city zz (Zhengzhou). The deepest hierarchy child-domain name is 501.01.chxy.zz.ha.cn. It means that this location is Room 501, No.01 Building, the Institute of Surveying and Mapping, Zhengzhou, Henan, China. The second DNS is a geographic domain system. From geo to river, Huanghe Valley and Jinshui branch, the deepest hierarchical child-domain name is Binhe-garden through the Institute of Surveying and Mapping.

In a certain domain, a domain name and its child-domain name have a subordinate relationship. We call it a relation and denote it with a solid line in Fig.1. Because of different compartmentalized rules in different domain and intersection among domains, there is an association in Fig.1 denoted with broken lines. In a domain, different locations can also have an association relationship.

With a hierarchical model, a local semantic location name can be extended to global. With association, bordering location can be denoted.

5 Location ontology

The semantic information of location concept is constant in the human brain. But in computer processing, this information should be described by ontology technology. A formalized ontology definition covers the following dimensional groups:

Ontology = (meta_info, Concept, Relation, Rule)

where meta_info is metadata about ontology (such as name, creator, create time, etc); Concept is the conception collection of ontology; Relation is the relation collection among these conceptions; and Rule refers to ubiquitous rules covering these conceptions[7].

OWL is a W3C nominated standard of ontology description language in semantic web[6]. It uses an object oriented method to describe domain knowledge. Since OWL can clearly denote the connotation and the relationships of conceptions in an ontology concept dictionary, it is used in this paper.

When we use OWL to model semantic location, we can set the location relationship to Relation dimen-
sion of location ontology and location property to Rule dimension. Now we discuss how to define the relationship among each location ontology instance.

From Fig.1 we know that there are two relationships between locations, i.e. relation (RelationTo) and association (AssociationTo). In OWL, these relationships are realized by object properties. When we define the property of RelationTo, TransitiveProperty is its basic character. It means location relationship is transmittable. For example,

\[ \text{RelationTo(chxy, zz) + RelationTo(zz, ha) } \Rightarrow \text{RelationTo(chxy, ha)} \]

SymmetricProperty is the basic character of AssociationTo property. It means the location relationship is symmetrical.

\[ \text{AssociationTo(chxy, dlyjs) } \Rightarrow \text{AssociationTo(dlyjs, chxy)} \]

As for Rule dimension, its properties must be defined by instance itself because of its own different characters. For example, for chxy, we have defined three basic rules: a speed limit of 5 km, free visits are forbidden, and no whistle.

We describe semantic location formalized by ontology because it has several advantages. The first is to make semantic location more obvious - it makes location properties and their relationship clearer. The second is that location ontology enables advanced sharing for semantic location. Furthermore, if every positioning service provider serves location ontology for formalized description, the application service provider can get information for more than one provider and allow a more perfect location value-added service. Lastly, location ontology can be understood by a computer and, with reasoning, provide more reference information for personalized preference services.

6 Semantic location application

Fig.2 is the flowchart of semantic location processing and application by ontology in personalized preference services LBS. The first step is to get a physical location from the positioning service provider. Supported by a spatial database, physical location can be converted into geographic location with simple semantic information. At the same time, the relationship of current location with its neighbors and some location properties can be derived from the spatial database. Combined with a location dictionary, this information can be organized in the front of location domain ontology by semantic description tools. A reasoning system will process the constructed location ontology with the help of an interior denotation model and interior rules. After a special ontology query and other information are fused, a personalized preference service will be established with object oriented computing. The last step is to display this service information on a user’s terminal.

There is a context option in most mobile phone terminals. This option allows the user to set the volume, telephone ring, key-press sound, background light, and other functions. Intelligent adaptive volume service is a context-aware personalized preference service in LBS. This service can automatically adjust the context option of a mobile phone terminal when the user context changes. For example, the NOKIA
3200 unit has five context options: standard, silent, beep, sonorousness, and user defined. If the user customizes this intelligent adaptive volume service, when he goes into a supermarket, the ontology description tools will add a noise context property in location ontology. The service constructor can read this noise information and send a message to the mobile phone controller to set a context option to sonorousness. When he steps out, this option will return to standard automatically. In a meeting room, maintaining silence is general knowledge. Because location ontology can tell a service constructor that this is the context, this service can set the mobile phone to silent mode.

When we construct this service, the positioning service provider outputs a numerical physical location without any semantic information. However, mining from location property and rule recognition allows a location ontology to be built. This semantic information can provide more reference information to develop a personalized preference service.

7 Conclusions

Location is the most important and basic information in LBS, but it has always been simply processed. After semantic mining, we can get much more useful information for a personalized preference service. This paper gives a correction of the semantic location concept, emphasizing that location property is another important component of semantic location. Using OWL to construct the location ontology, semantic location information can be read and processed by a computer. With a knowledge reasoning system, location ontology will provide much more important information to object oriented computing to establish the preference service.

Otherwise, a hierarchical model only denotes the relation and association relationship and cannot describe the complex spatial topographic relationship. This calls for further research to develop a new model for more perfect location ontology.

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