Location-based Context Awareness In Ubiquitous Environment

Jun-Sang Park[a], Young-Tack Park[a], Hyun-Jeong Lee[b], Jae-Doo Huh[b]
[a]Dept. of Computer Science, Soongsil University, Seoul, Korea
[b]Electronics and Telecommunications Research Institute(ETRI)
theartist@ailab.ssu.ac.kr, park@comp.ssu.ac.kr, hjlee294@etri.re.kr, jdhuh@etri.re.kr

Abstract

While researches on ubiquitous computing are actively in progress, the location data is largely utilized for knowing the user's current situation and providing adaptive services. Location data could be useful to provide necessary services to users automatically without explicit requests, detecting the relation between users' movement paths and objects modeled in the space in indoor environments such as home. In this paper, we propose a system which infers context semantics from raw sensor data based on location-awareness. First, in the sensor layer, the sensor data that implies the absolute location of objects is defined. Second, in the qualitative layer, we define the relative location among objects based on the sensor data. Third, in the relational layer, temporal and spatial relations are defined based on the cumulative data of the qualitative layer as time goes. Fourth, in the semantic layer lastly, we grant and define the meaning of relations among objects based on knowledge-based approach.

Key words: Ubiquitous computing, location-based service, context-awareness, semantics

1. Introduction

Because of concept of the ubiquitous computing which defined as "Computing access will be everywhere" has appeared and researched actively, it has been noticed for future-oriented technology (1),(2). It is crucial to know the user's location data in the service side, since we can use any devices as my computer anywhere and anytime (3). And firstly 'personalization' service would be considered for satisfying the person's expectation forcing more convenient life. In this context-aware system, we are aiming to provide adaptive services to users after being aware of user's demands previously as we infer the semantic meanings of user's behaviors based on location data. This system creates user's profiles through the inference and provides personalized services fitting their inclinations. Then it enables that provides automatic services satisfies the estimated users' demands with profiles provided from inference. First of all, we should define the vocabulary 'context'. Context implies the characterization of situation for providing adaptive services to users in ubiquitous environment. Then, we should know that why the context is required in ubiquitous environment. Perceived raw data from sensor couldn't influence on any users, that is, it has no meaning. As the location data transforms with meanings of situation, it is possible to provide the adaptive services to the users.

2. Location-based Context awareness system

The design of location-based context awareness system is centralized (4). We believe that it is not possible to process a system and infer the semantics by object's location data when all control and management functions are decentralized.

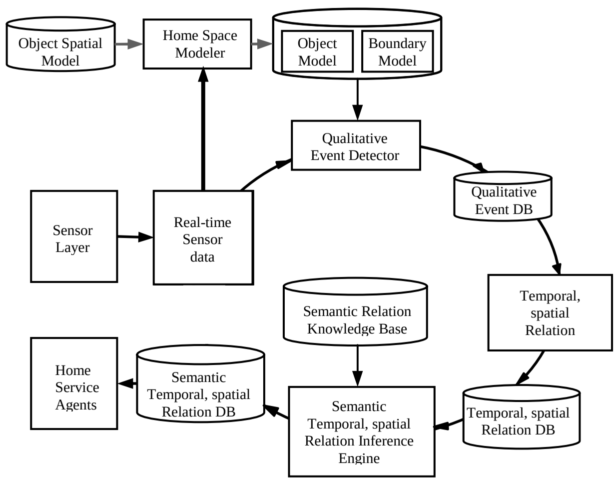

Figure1. Control flow of location-based context awareness

Figure1 shows the control flow of our system. Data creating in each layer would be stored at data base and transferred to the next step by real time.

2.1 Four-Layer based Context Awareness

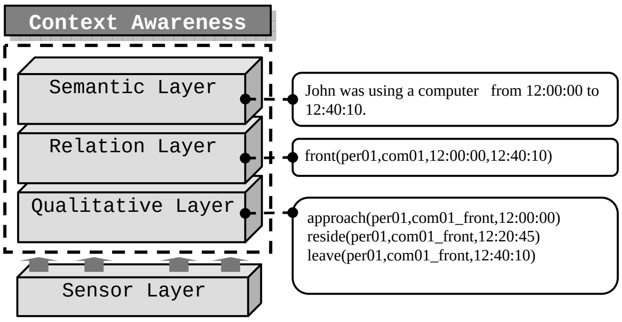

Figure2. Location-based context awareness layered architecture

Shown in figure2, context awareness is processing in 4-layered architecture. In the sensor layer that is the bottom layer, user movements are perceived and controlled. By real time, location-based sensors perceives four factors – the absolute coordinates X that a user located, the absolute coordinates Y that a user located, an user's identification and a user's orientation. The perceived factors are made into sensor data and they are transferred to qualitative layer, the upper layer. In the qualitative layer, qualitative events which represent relationship between a static object and a user are detected. For instance, "per01 is approaching com01 at 12:00:00" is a qualitative event as shown in figure2. Qualitative events are made into qualitative model and they are transferred to relation layer by real time. In the relation layer, relation model which represents spatial, temporal relations between a static object and a user are created based on qualitative model. Shown in figure2, "per01 was in front of com01 from 12:00:00 to 12:40:10" is relation model. In the semantic layer, to create semantic model which implies semantics around environment, the inference engine applies appropriate rules with relation model.

2.2 Spatial modeling

To model a spatial space, two types of components are needed – dynamic objects and static objects. We classified furniture and appliance which placed once and seldom changes their location as static objects. Location data of static objects is predefined by using real sensor or handling editor. The users or animals targeting of services are classified as dynamic objects. Described in section3.1, qualitative event detection module creates qualitative model, combining sensor data with an object property table. Object property table is composed of an object's identification, object's size and object's boundary size. As matching the object's identification of two components (properties of object property table and static object sensor data), world modeler constitutes a specific space as drawing static objects. According to getting dynamic object sensor data (real-time sensor data), qualitative model is created by applying the arithmetic equation. We are going to comment about the arithmetic equation at 2.4.

2.3 Sensor layer

First of all, accurate awareness of object's location data perceived by real sensor is important for Location-Based Service. The sensor data such as a dynamic object's identification, coordinates X, coordinates Y, orientation, and time is required in a system. So, we define the sensor data as (an object's identification, x-coordinates, y-coordinates, an object's orientation, time). The object's orientation could be considered as the orientation which object's body directs, object's visual orientation, and others. Among them we define the object's orientation as the object's body direction. The object's identification is recorded in sensors which attached to users.

2.4 Qualitative layer

Sensor data created in sensor layer is transferred to qualitative layer and used to detect qualitative events. Analyzing the real time sensor data, predefined static objects' location and properties are compared to detect qualitative events and create qualitative model. To detect the relation between a dynamic object and a static object, we calculate the area of static object's boundary by using arithmetic equations. Qualitative Model is defined by three vocabularies, `approach`, `leave` and `reside`. When a dynamic object such as user is going to contain in a static object's boundary, at that time we define as `approach`. The status that a dynamic object is fully contained in a static object's boundary, we define as `reside`. And a moment a dynamic object is going to be out of a static object's boundary, we define as `leave`. With these three vocabularies, we can be aware of relation between static objects and dynamic objects by every time.

Table1. Definition of Qualitative model

Type	Qualitative Model
Relation with Object's Body	*approach* (user, object, time)
	reside (user, object, time)
	leave (user, object, time)
Relation with Object's Boundary	*approach* (user, boundary_area, time)
	reside (user, boundary_area, time)
	leave (user, boundary_area, time)

For this qualitative modeling, there should be properties which determine static object's boundary and arithmetic calculation grasping the relational location between static objects and dynamic objects. Data about object's boundary is acquired from object property table. And for knowing the relational location between static objects and dynamic objects, we use the calculation of equation. We suppose that the object's boundary is square. Standardizing the object absolute location, four side lines of object's boundary make into four equations (e.g., x>10). Comparing four equations and a dynamic object location, we can identify the qualitative events.

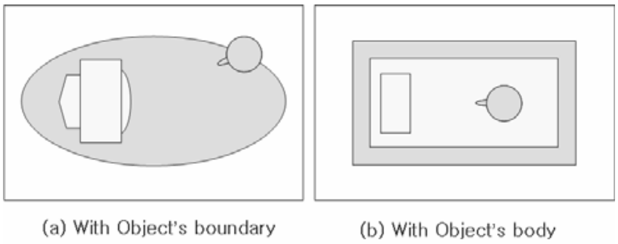

Figure3. Occurring qualitative events

Figure3(a) shows that an user is containing in the area of object's boundary. This state is represented as **approach**(user,boundary_area,time) considering the property of static object, it is the case that relative location between area of object's boundary and an user is meaningful, so the factor 'boundary_area' is assigned as second argument. Figure3(b) shows that an user is contained on the object's body. We represent that state as **reside**(user,object,time). The second argument assigns object since relative location between object's body and a user is meaningful.

2.5 Relation layer

In relation layer, the relation model which includes temporal and spatial concepts is created by using the qualitative model transferred from qualitative layer. The relation model is made by rule based inference. Shown in table2 and table3, relation model represents the relation between a dynamic object and a specific static object during specific time by using the qualitative model (e.g., approach, reside, leave). Relational model is defined by five vocabularies, front, rear, left, right and on, so they represents the relation between a static object and a dynamic object. The second argument at qualitative model boundary_area is divided into four representation front, rear, left and right considering the object's orientation. The front part of object's boundary is defined as front. In same manner, the left, right and rear part of object's boundary is defined as left, right and rear respectively.

Table2. front,rear,left and right in Relation model

Qualitative model	Relation model
approach (user, object's front/rear/left/right, timeA)	*front* (user, object, timeA, timeL) *rear* (user, object, timeA, timeL) *left* (user, object, timeA, timeL) *right* (user, object, timeA, timeL)
reside (user, object's front/rear/left/right, timeR)	
leave (user, object's front/rear/left/right, timeL)	

Table2 shows a mapping table of qualitative model and relation model that represents the relation between an area of static object's boundary and a dynamic object (e.g., user). When a flow of qualitative model is approach-reside-leave, not considering frequency of reside occurrence the relation model is created. For example, grasping the sequential flow that the point a user was approached to the area of object's boundary, the point a user was resided in the area of object's boundary and the point a user was leaved from the area of object's boundary, the relation model 'front' which means a user was existed in front part of the object from the time user approached to the time user leaved is used to model relational meanings. In the same meaning, rear, left and right is defined by using mapping table which applied some simple rules, so the relation model that includes temporal and spatial concepts is created.

Table3. on in Relational model

Qualitative model	Relational model
approach (user, object, timeA)	*on* (user, object, timeA, timeL)
reside (user, object, timeR)	
leave (user, object, timeL)	

Shown in table3, relation model on has different properties from the other relation model defined previously. Although the other relation model represents the relation between the area of object's boundary that defined appropriately to object's property, relation model on is representing the relation between an object's body and a moving user.

2.6 Semantic layer

The semantic layer creates contexts for providing services through semantic inference engine based on rules. Those contexts are made into semantic model fitting specific format. The aim of semantic model is to know the facts what a user does with a static object. Therefore, appropriate rules for a static object have to be applied to perform the adaptive inference for providing user desired services.

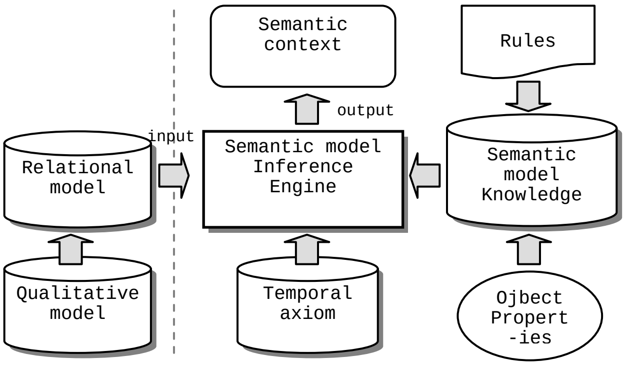

Figure4. Semantic model inference engine with inputs and outputs

Figure4 shows an architecture that acquires the semantic contexts by inference which is based on relational model data and some rules. Rules organizing semantic model are dependent on the types of static objects. The rules are predefined that considers properties of static objects and temporal flows. The predefined rules would be referred when the semantic model inference engine needs. When relation model at relation layer is creating, it transfers to semantic layer and is used for inputs of semantic model inference engine. By real time, the semantic model inference engine performs forward chaining or backward chaining to infer.

Table4. TV instance in semantic model

Relation Model	time	Semantic Model
front(user,TV,Tb,Te)	Te -Tb >= 60sec.	*watching*(user,TV,Tb,Te)
front(user,TV,Tb,Te)	Te-Tb < 60sec.	*beingFront*(user,TV,Tb,Te)
rear(user,TV,Tb,Te)	Te-Tb < 60sec.	*beingRear*(user,TV,Tb,Te)
left(user,TV,Tb,Te)	Te-Tb < 60sec.	*beingLeft*(user,TV,Tb,Te)
right(user,TV,Tb,Te)	Te-Tb < 60sec.	*beingRight*(user,TV,Tb,Te)
on(user,TV,Tb,Te)		none

Table4 shows semantic model of a static object `TV` for instance. When the relation model `front(user, TV, Tb, Te)` is used for inference engine, the semantic model inference engine refers the semantic model knowledge base to apply appropriate rules. `front` that implies relative location of objects and `TV` that implies type of objects are unified to appropriate rules in the engine. Through comparing time intervals, when a user's staying time (Te-Tb) is equal or greater than 60seconds, the engine infers that a user watched television. In contrast to, when a user's staying time is less than 60seconds, the engine infers that a user was just stayed in front of television. To watch television, a user must be in front of television in a scalable way. So the other relation model such as `rear`, `left` and `right`, are not meaningful in this case. For help to understand about this application, we show procedures of forward chaining inference of contexts about `TV`. We suppose that the relation model `front(hong, TV, 03:10:25, 08:30:00)` is getting to the semantic model inference engine. The engine searches the list of rules about static objects predefined in the semantic model knowledge base, and refers a rule about object `TV`. In this case, `hong` is unified to `user`, `08:10:25` is unified to `Tb` and `08:30:00` is unified to `Te` that it refers the relation model `front(user, TV, Tb, Te)`. The engine also considers temporal flow, `08:10:25 - 08:30:00 >= 60sec` is proved true, the semantic model `watching(hong, TV, 08:10:25, 08:30:00)` is created by matching the referred rule.

3. Future work and remarks

We will automatically provide appropriate service to users by context semantics the system inferred. In this system, we are aware of the location-based data and infer high level semantics at relation layer. Semantic layer will be modified later study. In future research, we will use clustering and learning on context semantics. So, user's behaviors may be predicted and user is getting automatic customized services.

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