LOCATION MODELING FOR UBIQUITOUS COMPUTING BASED ON A SPATIAL INFORMATION MANAGEMENT TECHNOLOGY

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Abstract. Location modeling, which generally has influence on location-aware applications, is a critical and interesting aspect. In the ubiquitous computing, location modeling has been discussed as one of fundamental research subject, because a location is a very essential element of contexts and useful information for other applications related with ubiquitous computing. Especially, location modeling in architectural space should be defined through the comprehension of the physical environment, because the users' (or objects) location does not only mean numerical coordinates, but also refers to the situation related to users' (or objects) physical contexts. In other hands, location model for architectural space should be based on the simplification of complicated physical environment, the consideration of corresponding various changes, and also the definition for the relationship of spatial information. Traditionally, those issues have been actively studied in the fields of CAAD (Computer Aided Architectural Design) research and could used effectively for ubiquitous computing system. This paper proposes the location model and its utilization method which can be applied on making the ubiquitous computing system in the architectural space based on CAAD theories. At the end of the paper, we present a CAAD system, called “Vitruius”, in order to define architectural spaces appropriately and manage them easily for the ubiquitous computing environment.

1. Introduction

In ubiquitous computing environment, in order to offer appropriate services to the user, a context-aware system has to recognize the situation and environment of the user such as emotion, health condition, time, schedule, weather, temperature, humidity, location, etc. Especially, location-awareness is the most fundamental part of the context-aware service, because location is a fundamental information for many applications related to ubiquitous computing.

Context can be regarded as a key factor of everything that effects computation except the explicit input and output (Thomas P., 2001). The output is completely determined by the input. Context-aware system decides what to do according to clear input and context basis, as consequence, it affects not only the explicit output, but also the context. Context is tacit and can explain explicit outputs, and also make more effective interactions. Figure1.1 shows us what is included in the context and its effectiveness about input/output. The locations of spaces, objects and users, are an important part of the context that a ubiquitous computing system has to aware. For the sake of offering appropriate services to users in the ubiquitous computing, the system should aware clearly the user's location that can be obtained by a well-defined location model related to spaces, building components, and objects.

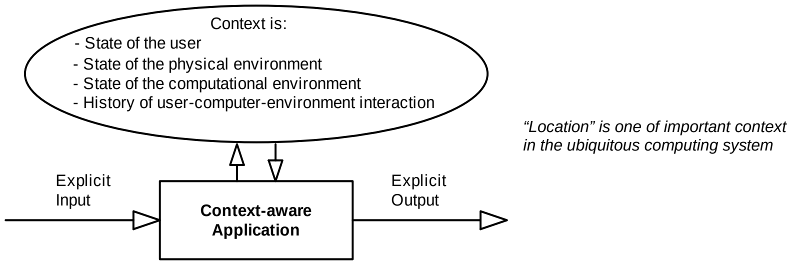


Figure 1.1. Context is everything but the explicit input and output

This paper proposes an effective location model and its implementation which can be applied to make a ubiquitous computing system in the architectural space based on some CAAD theories such as "Strplan"(Choi, 1997). First, based on the review of several related studies we create a new location model semantically defined, named. At the end of the paper, we present a CAAD system, called "Vitruvius", in order to define architectural spaces appropriately and store/manage them easily for the ubiquitous computing environment.

2. Location Model and Ubiquitous Computing

2.1. LOCATION MODEL

There are basic models of location representation, which are distinguished specification from abstraction. Physical and geographical models are absolute specifications. Those are represented by universally valid coordinate system, geographical names, and reference systems. On the other hands, geometric, symbolic, and combined (hybrid) models are more abstract and easier to adapt to automatic processing. The geometric model is represented based on the reference coordinate systems by points, areas, and volumes. So it is called as a metric model or a coordinate model. The symbolic model is a description using abstract symbols or names which are organized hierarchically. Such a representation makes it convenient for human interaction. It is a so-called hierarchical model or a topological model (Svetlana D. 2001).

Research about the location model has been advanced in the field of Location Based Services (LBS) based on Global Positioning System (GPS) and Geographic Information System (GIS) in the mobile environment. GPS is an appropriate position sensor for outdoors location. However it has many limitations such as signal acquiring times and shadowing from buildings. Therefore, some studies such as the user-centered location model (Natalia M., et al., 2001) suggest a set of locations which are learned by observing the user's patterns of mobility. This model also includes knowledge about the different patterns and destinations and it's integrated into context-aware mobile systems. Another study introduces an augmented form of location modeling to allow for a comprehensive range of sophisticated location based services in 3G networks (Stefan G., et al., 2001).

Since ubiquitous computing systems have been concerned, the focus of the location model has been moved from outdoor's location into indoor's location to offer better services or to provide the users with their current positions along with spatial information. In some ubiquitous computing projects, such as the Aura Project at Carnegie Mellon University, automatic adaptation of the computing environment according to the user's context is one of the key techniques. Therefore, these systems adopted computable location identifiers and used hybrid models to handle spatial queries for context-aware applications (Changhao J., et al., 2002). Recently the AwareHome project of GIT has discussed the topic about the need for a system to coordinate location information (Thomas O., et al., 2001).

In spite of a great deal of research efforts about location modeling, most of these efforts were modeling mobile user's locations in a wide area (Frank D., et al., 2003) or modeling locations in a local domain through one or two spaces of the application testbed. (Changhao J., et al., 2002) It is, therefore, difficult to consider a spatial network and attributes in a general space of building. Also it is hard to represent the relation with building materials. To overcome these limitations, some problems should be addressed.

- Consideration on multiple spaces
- Simplification of complicated space shape

- Reflection of user's intent
- Correspondence to the change of space
- Easy management of data

2.2. LOCATION MODEL IN UBIQUITOUS COMPUTING

One of the important roles for ubiquitous computing is the ability to determine where people are, what objects and software services can be used at those locations, and how people can move from place to place.(Mark W, 1993) That is to say, location provides information about activity and intent, and provides information about the devices available to the user, which allows determination of what will be effective means of communicating with him/her.(Mark W, 1993) Of course, the position of users or objects should obtain from the tracking devices such as sensor, camera, etc., but these numerical coordinates from them are not enough to explain the situation according to its location. In order to interpret the numerical coordinates to meaningful location, the ubiquitous system needs a kind of framework as means of transformation, because the location is significant information about the physical world, objects and users, beyond the set of numbers. In this manner, a location model is an abstraction layer between sensors and the system, and a shared metaphor with people (Barry B., et al., 2001).

Therefore, a location model in the ubiquitous computing system should be considered not only the fixed physical world but also moving users and objects, and also the model accommodates not only the numerical coordinates of them but also their relationship. In fact, a real user/object location, called 'semantic location' in this paper can be represented by the composition of geometric and topological information related with the structured physical world information.

3. Semantic Location Model

3.1. THE REPRESENTATION OF LOCATION

Monroe Beardsley (1958) suggests that "the form of an aesthetic objects is the total web of relations among its parts." in Aesthetic. Webster's, for instance, defines the form of a work of art as its "structured elements," specifically "the combinations and relations to each other of various components (as lines, colors and volumes in a visual work of art or themes and elaborations in an aural work of art)."

Architectural space could be comprehended in the same manner. Human does not recognize architectural space as an image, but as a hierarchical composition of various elements. Figure 3.1 describes a single indoor space composed of several building elements such as floor, wall, ceiling (or roof), door, and window. Each wall is connected with other sidewalls. Walls contain either doors or windows. Roof is on top of four walls. The limited space made of four walls is called “indoor space,” and the opposite is “outdoor space.” The door implies the connection of two spaces and it is the criterion of user’s transference. The window means that it is adjacent to the outside (or other space). The ceiling and the floor can signify the adjacencies of other spaces. We can also specify relationships of inclusion. For example, the wall, the floor, and the ceiling are a part of the room, and the door and the window are a part of wall.

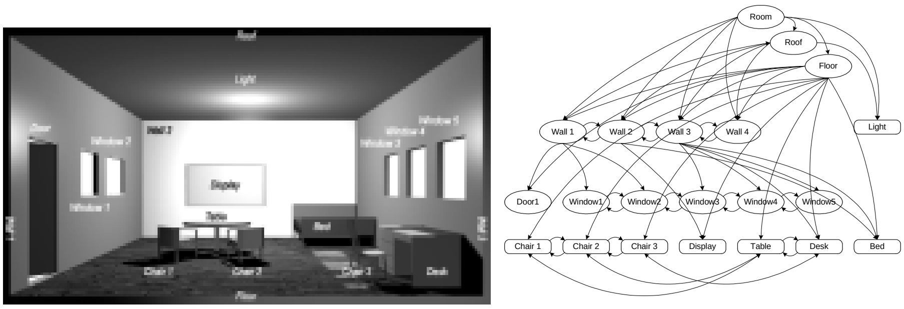


Figure 3.1. Inside view of single space(left) and The data structure for the semantic representation of single space(right)

Architectural space is the composition of various elements. Therefore, it is necessary to understand each occupant in the building as well as semantic structure such as linguistic comprehension shown in Figure 3.2.

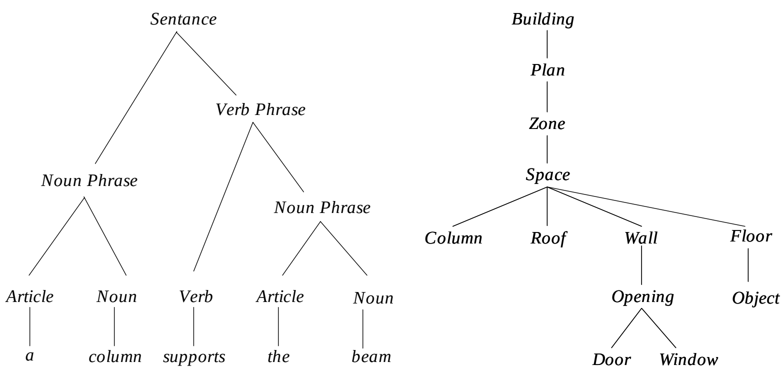


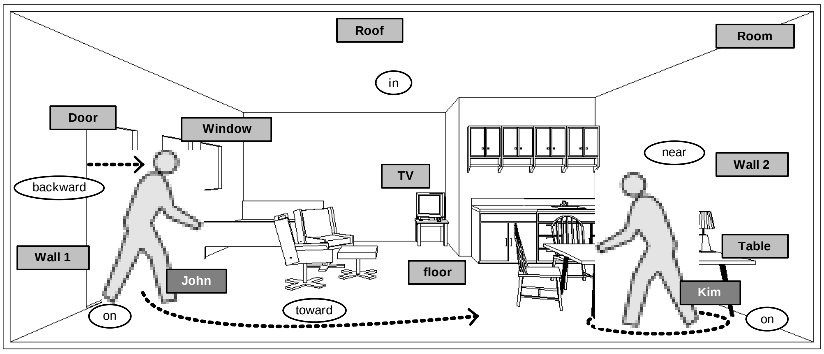
Figure 3.2. A tree diagram depicts the derivation and structure of a sentence and a building

However, buildings should be considered in a different aspect with spatial elements. First of all, spatial elements are usually regarded as the physical object itself, but buildings should be evaluated more than empty space. It has peculiar properties that differ from artifacts and also include spatial relationship and social meanings. Furthermore, buildings are not just objects, but empty volumes created by them. Therefore, architectural space could be understood by the syntactic characteristics of space or spatial relationship among spaces.

The user's (or object's) location is generally defined based on this structured spatial information that contains the relationship of elements and spaces such that "Kim is in the room, on the chair, beside yellow wall", "TV is on the table, in the next room of mine." Also, the user's location is defined by other users such that "Tom is near John." In figure 3.3, the location of John and Kim can be described variously such as "from desk, from door, from Kim, etc." Besides, the user's location is divided into two classes: static and dynamic locations. The static location contains "in", "on", "near", "beside", etc. and the dynamic location contains "toward", "backward", "down", etc., shown in Table 1. The dynamic location can be changed in the real-time manner.

TABLE 1. Preposition for Static/Dynamic location

Prepositions for …	
Static location	Dynamic location
in, on, by, near, beside, next to, inside, outside, over, above, below, between, under, behind, at, in front of, opposite, to, etc	toward, backward, in direction of, down, up, into, out of, through, against, across, away from, along, round. etc



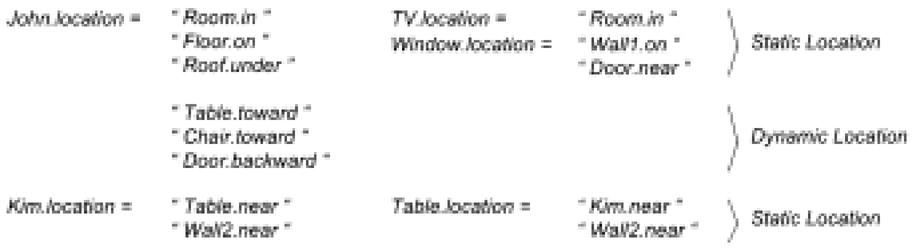


Figure 3.3. The description of location

Consequently, a location is not a numerical position or a coarse simplified situation, but semantic information that contains the relational information between users and objects. Therefore, the ubiquitous computing system needs the well-defined location model that can describe the relationship of user and objects related with the characteristics of architectural space. Of course, tracking user's position is essential, but it is not enough for an effective user-centered service. Figure 3.4 shows the relation of elements that compose spaces as a UML diagram.

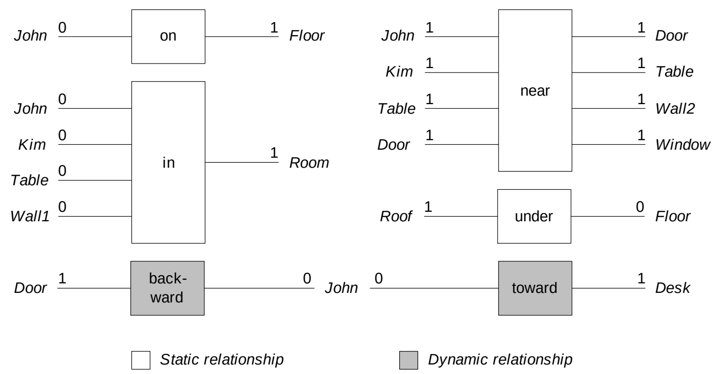


Figure 3.4. A UML diagram of user/object/space/spatial element

3.2. WHAT IS "SEMANTIC LOCATION MODEL"?

Recently, "semantic web" is becoming a very interesting concept on the Internet. The semantic web can be defined as the representation of data on the World Wide Web, an extension of the current web in which information is given well-defined meaning (Tim L., et al., 2001).[1] In the same manner, a

[1] http://www.scientificamerican.com, Tim Berners-Lee, James Hendler, Ora Lassila, The Semantic Web, Scientific American, May 2001

semantic location model can be understood, which has a well-defined data structure of situation according to its location. A semantic location model can make the description of physical situation exact and rich, because it has both geometrical and topological information. Figure 3.5 shows the concept of the semantic location model that is a composition of geometrical and topological information. Geometrical information depends on distance measurements, while topological information means relationships among spaces, spatial elements, objects, and users.

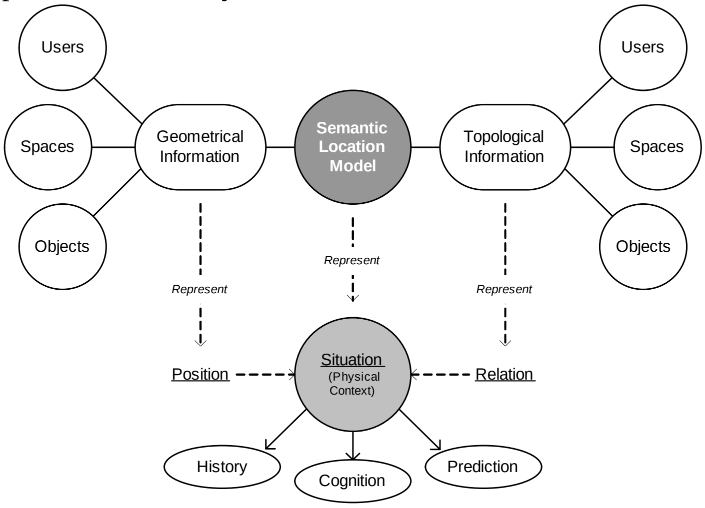


Figure 3.5. The concept of the semantic location model

3.3. SEMANTIC LOCATION MODELING

There are lots of considerable factors to solve in order to make an effective location model such as definition for the relationship of spatial information, simplification of complicated physical environment, correspondence of various location changes, and amassment of location information, etc. Traditionally, these problems have been studied actively in the fields of CAAD and could be applied effectively to develop a location model for ubiquitous computing systems. In order to make a semantic location model, as previously stated, there are several strategies including:

- The appropriate definition for symbols of location and their relationships: a location model should not only consider the characteristics of architectural space, but also be created on the basis of them.

- Correspondence to the change of space: an object-oriented data structure should be used.
- Reflection of user's intention: a location model should not only recognize the exact user's location, but also the history and prediction of user's location.
- Consideration of multiple spaces and users: the ubiquitous computing system is not for a single space and users at all. A location model can be used for multiple space and users.
- Standardization of file formats: a location model for the ubiquitous computing system can use heterogeneous software and devices.
- Consideration of static and dynamic locations.
- Easy management of data: an actual architectural floor plan is too complicated to be used for a location-aware system. The simplification of floor plan data is required for the location model.

This paper proposes a new location model based on 'Strplan', shown in Figure 3.6. Strplan is structurally well-defined and also has some hierarchical components. To make it more effective, we consider a component-based and object-oriented approach so that the system recognizes the spatial network as well as relationship between space and building materials. The component has its own data and methods of how to operate in certain situations. Strplan has the following special features such as: 1) an object-oriented approach, 2) definition of relationship between objects, 3) management of spatial information and its relationship, 5) instant and consistent management of information, 6) level of details, 7) auto-generation of 3D model, and 8) foundation of a robust building data model. Strplan is suitable to make semantic location model.

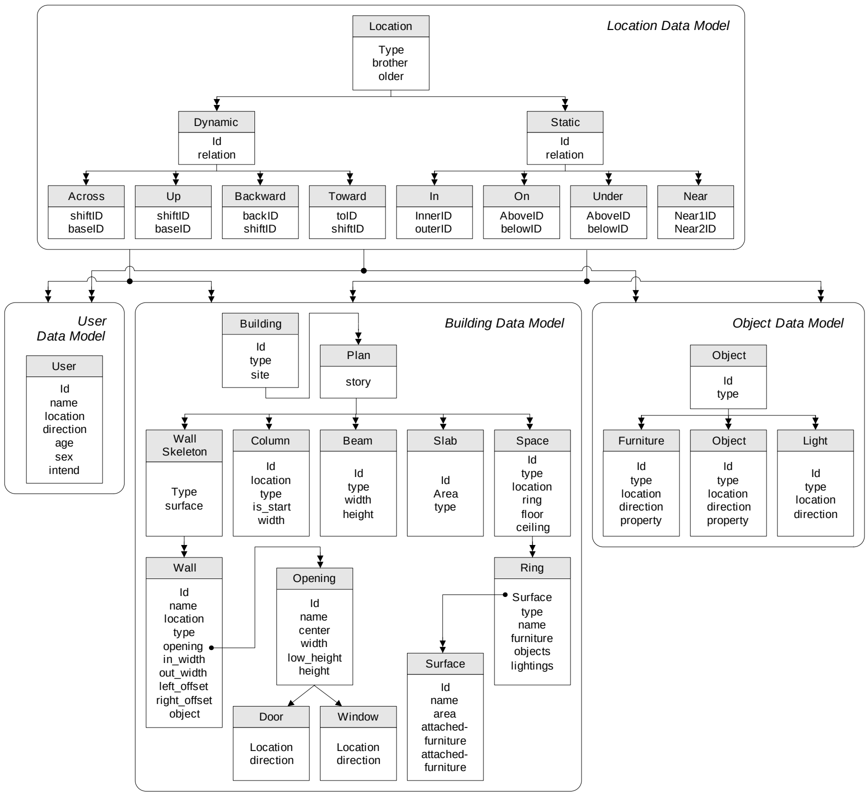


Figure 3.6. The data structure of semantic location model

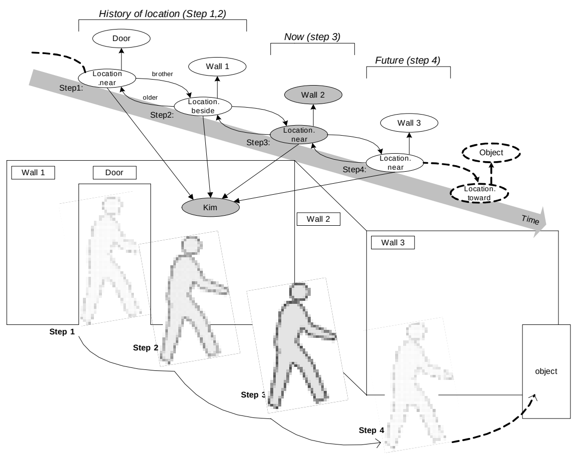


Figure 3.7. The example of using the semantic location model

4. Vitruvius: a kind of CAAD System for Semantic Location Model

4.1. INTRODUCTION OF 'VITRUVIUS'

In this chapter, we present a specific CAAD system, named "Vitruvius." Viturvius, based on the semantic location model we develop, can authorize and store locations efficiently, as previously stated. The location database can be used effectively as predefined communication interface information in the ubiquitous computing system.

Vitruvius semantically recognizes the human location related with the space and spatial elements, and indicates the location based on the semantic location model (Figure 3.6), shown in Figure 4.1.

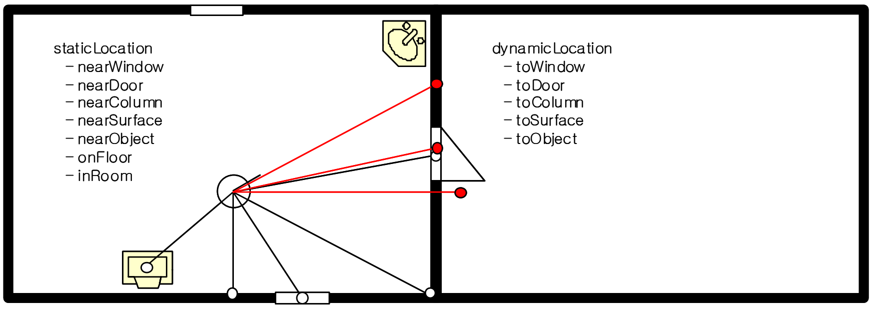


Figure 4.1. The example of the human location in Vitruvius

4.2. SYSTEM IMPLEMENTATION

As soon as the human location is identified, Vitruvius is automatically setting the nearest building components such as surface, wall, door, window, column, and object on the floor within that room. Figure 4.1 shows the example of human location that presents both the static location and the dynamic location in Vitruvius. We have implemented a 'LocMode' in the Vitruvius system. This mode can show the nearest components and the direction to move, and the room to move. The simulation of the semantic location model is such as Figure 4.2, under several spaces and users.

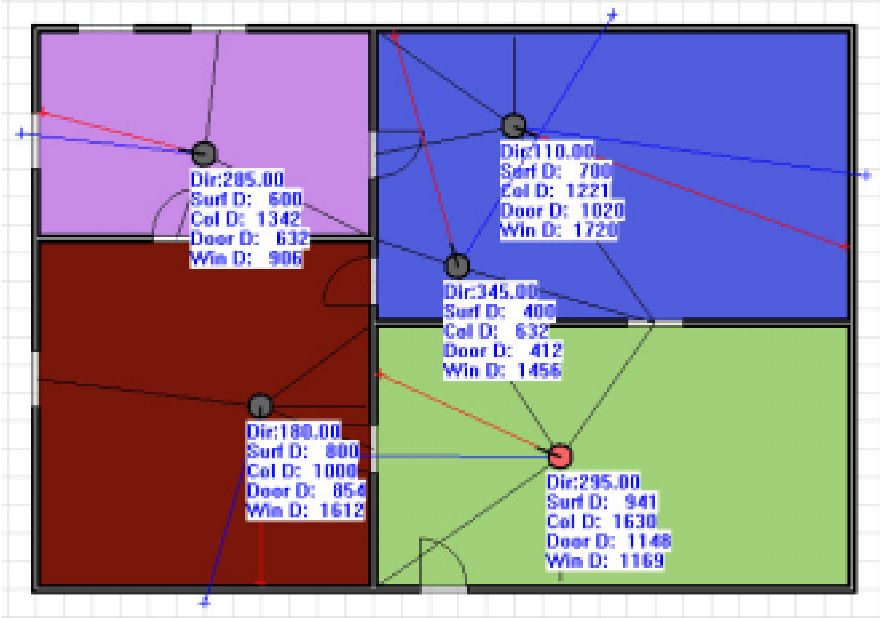


Figure 4.2. The simulation of the semantic location model in Vitruvius

4.3. ADVANCED APPLICATIONS

The semantic location model in Vitruvius can be applied to various applications for the ubiquitous computing environment. In this paper, we suggest the two applications: visible area checking and a prediction model.

Visible Area Checking

When a person is placed in a space, the visible view angle is defined. According to this range, Vitruvius automatically discovers a visible area. Figure 4.3 explains the process of visibility checking by calculating the visible area in the space. It is important that ubiquitous system recognizes the visible area of the person based on the semantic location model, because it could make the indoor LBS more efficient and complete.

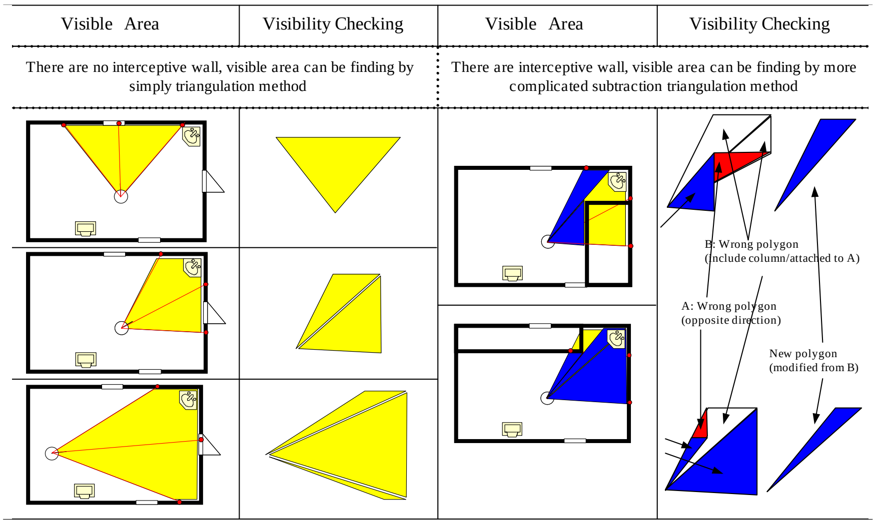


Figure 4.3. The process of visibility checking

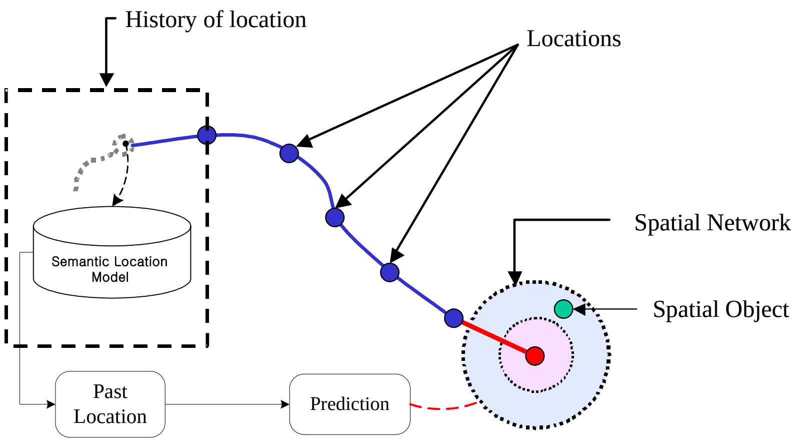


Figure 4.4. The concept of History of Location and Prediction Model

Recording Semantic Locations for a Prediction Model

We can consider another challenging research about the location model. Optimizing the semantic location model in Vitruvius, the semantic information of a person's movement and path can be saved as a data set. To do so, when the data is overloaded, it is recorded in the database as a previous location. The database, thus, accumulates a history of the person's semantic locations. Based on a sequence of semantic locations we can develop a so-called prediction model to support more intelligent LBS (Location Based Service) with semantic information in the ubiquitous environment.. The concept diagram is shown in Figure 4.4.

5. Conclusion and Discussion

In this paper, we suggest a new location model that contains the well-defined data structure based on the spatial management technology, named a “semantic location model.” At the end of the paper, we introduce a prototype CAAD system, called “Vitruvius,” developed on the base of the semantic location model.

The semantic location model is a well-defined data structure of situations related with positions. The model can make the description of physical situation exact and rich, because it has both geometrical and topological information. The ubiquitous system utilizing it can recognize the context about user’s location and offer appropriate services to the users. In addition, this paper presents the prediction of user’s intent and the recognition of visible area using the semantic location model in Vitruvius. The proposed location model can be applied to the ubiquitous computing system such as LBS, virtual reality / augmented reality environments, intelligent buildings, etc. For future research we need to study various applications in depth..

Acknowledgements

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