Development of Semantic Model of Multi-Level-Building Navigation Using Indoor Ontology and Dijkstra's Algorithm

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Abstract— **Location based services (LBS) can be separated into a number of layers: technology layer, application layer, standard layer, and social-ethical layer. This paper presents an ontology development at standard layer. We developed an ontology to identify and classify indoor semantic information to guide the development of LBS applications for multi-level building navigation. This ontology proposed models of multi-level building properties as classes of building, level, zone, link, node, and coordinate. To apply this ontology, we develop an indoor navigation algorithm using the ontology classes and Dijkstra's algorithm for shortest path in user navigation. A prototype and experiments are implemented to validate this ontology.**

Keywords—knowledge based systems, ontology, location based services, smart city, indoor navigation

I. INTRODUCTION

Location based services (LBS) are becoming one of major functions in smart city. LBS has a number of layers: such as technology layer, and application layer. On technology layer, most of indoor navigation efforts have been largely focusing on navigation technologies using sensors and positioning algorithms [1]. The outcomes of navigation outputs are mostly on mathematical and geographical information such as coordinates of an indoor object.

On application layer, most of the efforts have been on developing service applications. Examples of applications include: user navigation in buildings, location based advertising, searching specified location in buildings, location based games, people or object indoor tracking, industry warehouse operation, and user shopping behavior analysis.

These applications provide software and devices for users to complete service functions in specified indoor environment, such as in a shopping mall in Sydney CBD, or in a warehouse in Sydney suburb.

In design of location based services, there is no adopted standard for LBS so far. There is a need to build a knowledge base and sematic standard for indoor location in LBS. This knowledge base is to build the model in indoor environment for users to search, track, and navigate semantically. Researchers proposed modelling language such as IndoorGML [2] to represent indoor space information using XML schema.

Ontology can be a knowledge based approach to build standard for LBS. In our research, we develop indoor navigation ontology for LBS. In this paper, we present the development of indoor navigation ontology and the validation process using prototype and experiment in real multi-level building environment.

This paper is organized as follows. Section II reviews related work. Section II presents the indoor navigation ontology for multi-level buildings. Section IV presents indoor navigation process design using the indoor navigation ontology, and validates the ontology using prototype and experiments. In the last section, conclusions are drawn.

II. RELATED WORK

To consider the concerns of different stakeholders, location based services can be separated to a number of layers. The following table identifies the layers and their functions.

TABLE I. LBS LAYERS AND FUNCTIONS

LBS Layer	Function
Technology Layer	Provide LBS technologies using positioning sensors, systems and end user devices.
Application Layer	Provide end user software and hardware packages to satisfy user demand.
Standard Layer	Build knowledge base, make consistency in LBS market and LBS system development, and speed up LBS application development.
Social-ethical Layer	Evaluate impacts of LBS in social ethical area.

Technology layer is the first layer using outcomes from research and technology innovation. Scientists discover the nature of the sensors, and engineers build solutions using sensors. The current positioning technologies used for LBS include: Global Navigation Satellite System (GNSS), wifi, radio frequency signals (RF), visible and infrared light, inertial sensing, ultra sound and audible sound, magnetic field, zigbee, radio frequency identification (FRID), ultra wideband (UWB), blue tooth, and computer vision [1, 3, 4, 5,6,7].

At application layer, location based services use the values of location and user demand to provide functions to users from government to citizens [8, 9, 10]. One of the LBS examples in our university is UTS Wayfinding, which provides location functions within university campus for students, staff and visitors [10].

At social-ethical layer, researchers have been defining social-ethical framework to evaluate the values, capabilities, risks, trust, privacy, cultural sensitivity and other possible impacts of location based services [11,12].

Applications in LBS markets and research prototyping are developed for user demand in case by case. There is a need to develop LBS standards to guide the LBS development, to build knowledge base, to provide best practices, to make consistency and speed up the LBS development. This need requires a separate standard layer in LBS as in Table I.

Software development industry uses Unified Modeling Language (UML) as a standard language to specify, design, and implement software systems [13]. The Open Geospatial Consortium (OGC) proposed modeling languages CityGML to represent location semantics using XML-based format [14]. In indoor space, researchers proposed IndoorGML to model indoor space properties, and provide indoor space references [2].

Ontology is the concept to describe types of properties and interrelationships of all the devices in this system. For example, in the LBS ontology describe the online database which contains all the information from passive RFID [15]. There are three models of ontologies in computer systems: top-level ontologies, lexical ontologies, and domain ontologies. In a different situation, we will applicate different kinds of ontologies to deal with information [16, 17, 18].

In our research, we developed an indoor navigation ontology in multi-level building for LBS knowledge base. We will present this ontology and analyse the ontology using ontology validation process.

III. DEVELOP MULTI-LEVEL-BUILDING INDOOR NAVIGATION ONTOLOGY

We design the multi-level building ontology for indoor navigation using a class diagram. Figure 1 is the ontology architecture.

The classes and attributes are designed as follows.

- *Building*

TABLE II. lists all the required attributes for the class *"Building*". Building is the main class to contain all the sub-classes, and it creates all the functions and navigation process.

<u>*BuildingId*</u> is the unique id for class "Building".

<u>*BuildingName*</u>: a name to display to users.

<u>*GlobalPost*</u>: is designed as the global position in global map. It is pre-defined using outdoor navigation. It is used to identify the physical position of this specific building.

TABLE II. BUILDING

Attribute	Example
BuildingId	UTS_11
BuildingName	UTS Faculty of Engineering and IT
GlobalPost	Building 11 University of Technology Sydney

- *Level*

The "level" is the class generated by the main class "Building" and generally represent the vertical factors in the navigation system.

<u>*LevelId*</u>: The unique id for this class. It will be used as the vertical coordinates.

<u>*LevelName*</u>: The second identity for this level, and it is generally used to display to users.

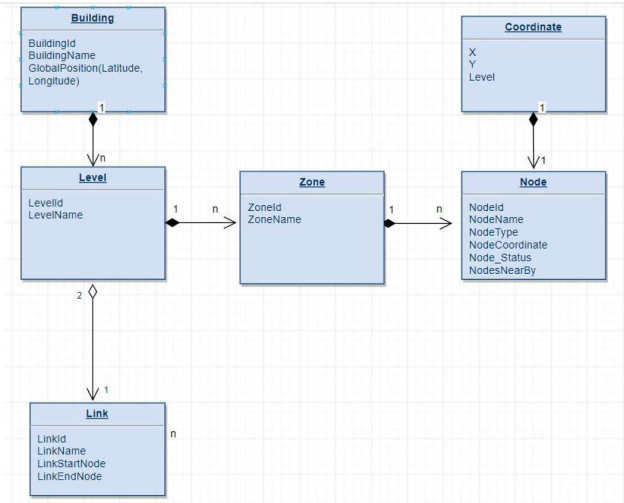

Fig. 1. Multi level building ontology for indoor navigation

TABLE III. LEVEL

Attributes	Example
LevelId	8
LevelName	Level 8

- *Link*

Link is one of the special design in this ontology, it defines one virtual connection between levels which will start from one node to another node in the different levels. "Node" will be described in another class. Table IV describes the design of the attributes of 'Link'.

TABLE IV. LINK

Attributes	Example
LinkId	809_1
LinkName	No.1 link from level 8 to level 9
LinkStartNode	14 (unique id of a link node from level 8)
LinkEndNode	26 (unique id of a link node from level 9)

<u>*LinkId:*</u> Unique id and the primary identity for this "Link".

<u>*LiknStartNode:*</u> Unique id for the start node from the start level, and the type of this node must be 'Link' node.

<u>*LinkEndNode:*</u> Unique id for the end node from the target level, and the type of this node must be 'Link' node.

It is not limited to have many links between two levels, as long as there are enough 'Link' nodes, but for particular pair of start node and end node, there must be only one "Link" exist in the system in case errors happen in the navigation process.

- *Zone*

The zone is a concept which indicates an area or a set of areas in a building for building management purpose. Table V shows the design of "Zone" and examples.

TABLE V. ZONE

Attributes	Example
ZoneId	801
ZoneName	Offices for professors

ZoneId: The unique identity for one Zone. The formatting is designed as " level+0+No." The level is the level number where this Zone belongs to, and "No" will be the number of the Zone in a level.

ZoneName: The second identity for class 'Zone' to display to users.

- *Node*

Node is the most important class in this ontology, especially it is the smallest object in the whole data modelling system. Node represents a specific location or small area. Conceptually, the pathfinding process can be considered as a list made up of a set of nodes, which have a special order, distances and relationships.

TABLE VI. NODE

Attribute	Example
NodeId	10
NodeName	CB11.08.200/OFFICE
NodeType	node
NodeCoordinates	(9,4,8)
NodeStatus	1
NodeNearyBy	9,11

NodeId is the unique and primary identity for a node. A node could be frequently used in not only route finding and nearby node searching processes.

NodeName stores the information about the name of this node.'CB11.08.200/OFFICE' is an example of NodeName.

"*NodeType*" is the most important design in this class, this attribute is the key used to classify the nodes and each of them has different functionalities. Two types are listed: 'Node' and 'Link'.

TABLE VII. NODE TYPE

Node Type	Description
Node	The normal node which represents a room, space or a small area.
Link	The special node which can connect with different levels, e.g. elevators, lifts and stairs.

NodeCoordinates: In a navigation system, it is critical to identify where the node is and how to calculate the distance between two nodes. Therefore, the attribute *NodeCoordinates* was created to define the position of a node. TABLE VIII. describes the design of *NodeCoordinate*. The coordinates were defined with three factors (x,y, level).

TABLE VIII. NODE COORDINATE

Factor	Explanation
x	The x in the horizontal coordinate system.
y	They in the horizontal coordinate system.
level	The vertical coordinate for the node, generally the same as the level id of which this node belongs to.

NodeStatus: We assume that each node has the status which could be "On" or "Off", and the value '0' or '1' was used in this attribute. '0' means "On" and '1' means "Off".

NodeNearby: In the navigation system, there must be some rules to find the proper route. For example, a node cannot cross walls to the unreachable node. Therefore, the nearby nodes set was defined to show all the nearby nodes of a known node.

This ontology will be validated in the next section.

IV. VALIDATION OF MULTI-LEVEL BUILDING ONTOLOGY FOR INDOOR NAVIGATION USING PROTOTYPE AND EXPERIMENTS

The approaches to evaluate an ontology include: comparing the ontology with a standard ontology; applying an ontology to an application; comparing an ontology with data source in that domain to check coverage; domain experts assess the ontology to meet the predefined standard, criteria or requirements [19]. In our research, we use "applying the ontology to an indoor navigation application" to validate our ontology.

In the validation process, we designed the following phases: (a) design a validation algorithm for indoor navigation in a multi-level building. (b) develop a prototype for this application.

A. Indoor navigation algorithm

Fig. 2 is the validation algorithm to use the attributes in classes of the ontology. The aim is to achieve navigation between levels in high building.

User will input two nodes: StartNode and EndNode, the process is designed as follows:

- Judge if the StartNode and EndNode are in the same levels. The class "Node" contains the coordinates information node coordinates (x,y, level). Therefore, if the level of StartNode equals the level of EndNode, just run the same level navigation process. If not, go to the next step.
- The navigation system will generate two paths which happen in different levels and the navigation process will be broken down into three parts:

(1). From the start node to find the nearest "Link" node (node has NodeType with "Link" and we name this node as link1);

(2). Searching the matching pairs of class Link which has the LinkStartNode with link1 and the linked node with the paired "Link" node in the target level (we name it as link2).

(3). Start the same level of navigation from node link2 to the EndNode

- After we got two available route arrays (it was one if StartNode and EndNode are in the same level), print out the array in the right order.

After processing this navigation method, the complicated navigation process in different levels can be distributed into a few same level paths searching problems. And the rest of the task will focus on the same level path searching which applies the proper algorithm.

B. Algorithm implementation using Dijkstra's algorithm

In this ontology, the algorithm we used to apply the path searching in the same level is Dijkstra's algorithm which is well-used in the common shortest path searching problem. Because we defined the coordinates of the node which has the horizontal coordinate system: x and y can be used to calculate the distance between two nearby nodes:

$$Distance = \sqrt{(x1 - x2)^2 + (y1 - y2)^2} \quad (1)$$

Equation (1) above calculates the distance between two nodes (x1, y1) and (x2, y2). The following flow demonstrates the shortest path searching using Dijkstra's algorithm.

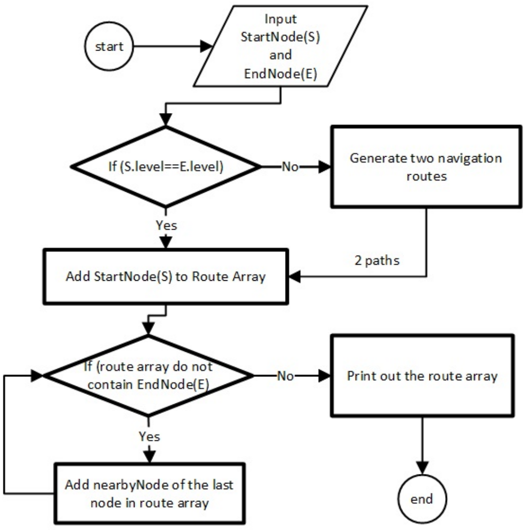

Fig. 2. Indoor navigation process using ontology

C. *Ontology validation using prototype and experiments*

We implemented a prototype using Java SE Development Kit 8 and IntelliJ IDEA Ultimate Edition. Experiments of indoor navigation using our ontology are carried out using this prototype. Figure 3 is the result in UI of the prototype.

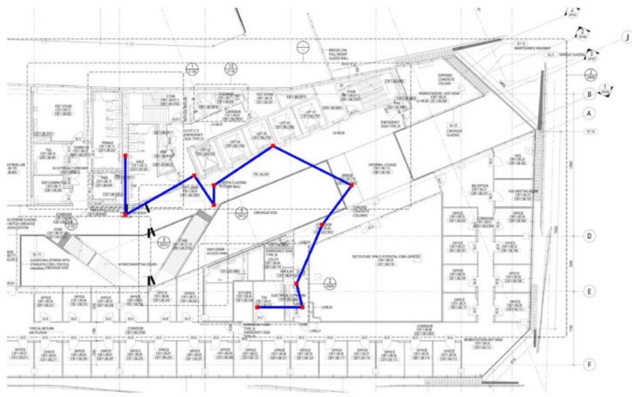

Fig. 3. Prototype UI and searching results in experiment

The experiment results using the prototype show:

(a) The prototype application displays the Building information using our ontology, and all the available nodes in this building, users are able to have a view on the nodes and start to consider the destination.

(b) The system will ask users for the input with node id for Start node and End node.

(c) The system is able to compute and display the shortest path and in both textually and graphically, include the instruction about how the application will lead the user to the lift to another level.

Our ontology is validated using the above prototype results in real building experiments.

V. CONCLUSION

In this paper, we presented an ontology approach for indoor navigation in multi-level building. This ontology built a semantic knowledge model for LBS. This indoor navigation ontology contributes to the standard for LBS application developments.

The ontology is validated by applying the ontology to an indoor navigation application.

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