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Location-based service using ontology-based semantic queries: A study with a focus on indoor activities in a university context

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ABSTRACT

Much research on three-dimensional (3D) indoor geographic information systems (GIS) to date has been focused on 3D topological modeling in the context of emergency management and response. Besides emergency situations, however, little is known about other human activities and the effective use and retrieval of semantically relevant information about such activities based on route analysis in complex buildings regarding 3D indoor GIS. This study proposes a location-based service (LBS) using ontology-based semantic queries with a focus on the indoor activities in a university context. An ontology model called 'University activity ontology' is designed with regard to the indoor activities at a university for sharing, managing and querying data semantically. In particular, reasoning rules are created for semantic queries to retrieve and provide information about places relevant to a destination with keywords given by users. A 3D network-based topological data model is generated by connecting a road network model and indoor topological network model to calculate the shortest path from an outdoor/indoor location to an indoor destination of interest selected by users among suggested choices. For the implementation, a location-based GIS application is developed based on the Android operating system (OS) with interactive two-dimensional (2D) and 3D visualization.

1. Introduction

The growing interest in three-dimensional (3D) geospatial information since the 1990s has led to a turning point in geographic information science (GIScience) toward complex 3D environments (Lee, 2004; Stoter & Zlatanova, 2003). With regard to three-dimensional geographic information systems (3D GIS), 3D topological modeling that seeks to define the relationships between geometric primitives for representing 3D objects has been a challenging and intriguing issue in 3D data modeling (Zlatanova, Rahman, & Shi, 2004). Many scholars in this area focused on the development of 3D topological models for various purposes (Arens, Stoter, & Van Oosterom, 2005; Molenaar, 1990; Shi, Yang, & Li, 2003; Zlatanova, 2000). 3D GIS have provided opportunities for extending the scope of study to micro-scale settings like indoor spaces, with a focus on the visualization and topological analysis for various applications, especially emergency response based on 3D network models (Kwan & Lee, 2005; Lee, 2004; Lee, 2007; Lee & Kwan, 2005; Lee & Kwan, 2014; Meijers, Zlatanova, & Pfeifer, 2005; Thill, Dao, & Zhou, 2011; Vanclooster et al., 2012; Yang & Worboys, 2015; Zhou et al., 2015).

Besides emergency situations, however, little is known about other human activities and the effective use and retrieval of semantically relevant information about such activities based on route analysis in complex buildings regarding 3D indoor GIS. People spend more than 90% of their time in indoor spaces (EPA, 1989) and thus human activities in indoor environments are of great importance. Human indoor activities can be described by various semantic information, like type (e.g., work or recreational activity), date, participants or duration. The amount of semantic information of human activities in a complex area like a university campus is especially huge and may change frequently, requiring efficient data management and query process. As smartphones have been widely used, people in such complex areas can easily reach destination buildings in which activities of interest happen, using commercial mapping applications (e.g., Google Maps). However, information retrieval for finding destinations through such mapping services is limited to a few ways of describing locations (e.g., building name, street address). Thus, the needs of mobile users who would like to search places with specific activity information are not met. In addition, providing information about not only destinations but also other places relevant to the destinations which users might want to visit will enrich the information content of the responses to users' queries. For this kind of

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0198-9715/

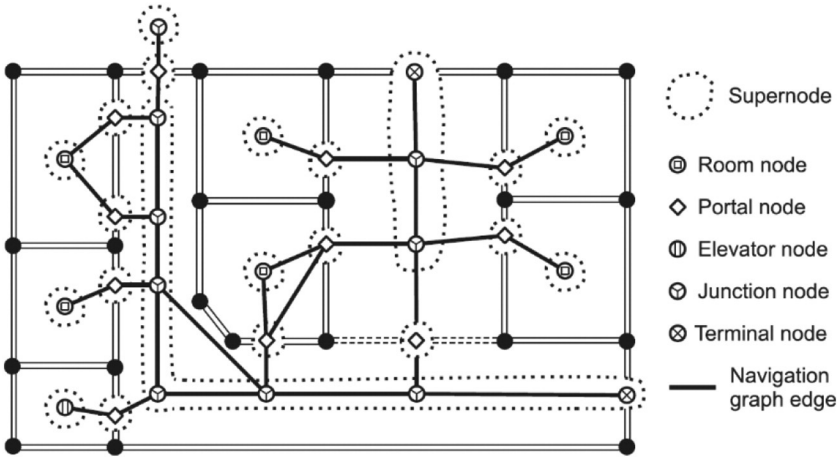

Fig. 1. Network-based topological model design by Yang and Worboys (2015).

applications, ontology-based semantic queries can greatly facilitate the search for relevant places in mobile computing environments through better querying indoor places and activities that people would like to engage in.

An ontology model is a framework for describing domain knowledge, taking into account pertinent concepts and their relationships (Gruber, 1995). The structured knowledge model in a specific domain can be shared, reused, and merged with other ontology models in different domains. Concepts and their relationships in an ontology model are represented as classes and properties with a hierarchical structure. The Semantic Web is implemented based on ontology models. It provides relevant information retrieval capabilities through various reasoning rules (Berners-Lee, Hendler, & Lassila, 2001; McIlraith, Son, & Zeng, 2001). The role of the Semantic Web has become important in the provision of more accurate and pertinent information. The use of Semantic Web technology based on ontology models may thus be effective in mobile computing environments.

Many past studies focused on the usability of ontology techniques for indoor navigation for production assets in manufacturing environments (Scholz & Schabus, 2014), seamless navigation in indoor and outdoor spaces (Yang and Worboys, 2011; Worboys, 2011), and indoor route planning (Anagnostopoulos, Tsetsos, & Kikiras, 2005; Dudas, Ghafourian, & Karimi, 2009; Kikiras, Tsetsos, & Hadjiefthymiades, 2006). Existing research, however, tend to neglect further implementation and the practical use of ontology models, and the proposed ontology models do not address human activities in indoor spaces. In addition, with the widespread use of smartphones, the integration of ontology and semantic techniques with location-based end user services needs to be considered. Thus, this study focuses on the implementation of an ontology model and the integration of the model with semantic queries related to human activities in indoor spaces. Compared to path suggestion or selection based on user profiles (e.g., pedestrians or the disabled) for route planning and navigation in existing ontology research, this study addresses the problem of providing smartphone users with a service that suggests a destination of interest and relevant places in indoor spaces and to provide them with more choices based on rich indoor activity information structured in an ontology model.

The purpose of this study is to propose a location-based service (LBS) using ontology-based semantic queries with a focus on indoor activities, using a university campus as a case for its development and implementation. A framework architecture is designed to describe the entire LBS system and its components. An ontology model called 'University activity ontology (UAO)' is designed with regard to indoor activities at a university for efficient semantic data management and semantic queries. In particular, reasoning rules are created primarily for complex semantic queries, which involve deduction that takes into account the multiple relationships among different concepts, to retrieve

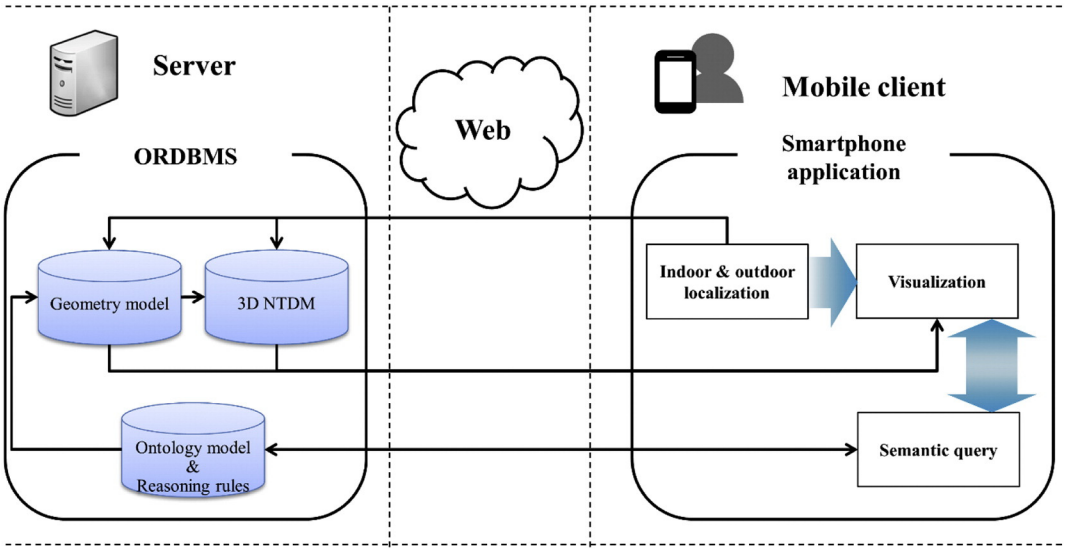

Fig. 2. Framework architecture of the LBS using ontology-based semantic queries.