Received: 11 January 2018 | Revised: 20 August 2018 | Accepted: 5 October 2018

DOI: 10.4218/etrij.2017-0246

ORIGINAL ARTICLE

ETRI Journal WILEY

Spatial experience based route finding using ontologies

Maryam Barzegar[1] | **Abolghasem Sadeghi-Niaraki**[2,3] | **Maryam Shakeri**[2]

[1]The Centre for Spatial Data Infrastructures and Land Administration, Department of Infrastructure Engineering, The University of Melbourne, Victoria, Australia

[2]Geoinformation Technology Center of Excellence, Faculty of Geodesy & Geomatics Engineering, K.N.Toosi University of Technology, Tehran, Iran

[3]Department of Computer Science and Engineering, Sejong University, Seoul, Rep. of Korea

Correspondence
Abolghasem Sadeghi-Niaraki.
Email: a.sadeghi.ni@gmail.com

Funding information
This research was supported by the MSIT (Ministry of Science and ICT), Korea, under the ITRC (Information Technology Research Center) support program (IITP-2019-2016-0-00312) supervised by the IITP (Institute for Information & communications Technology Planning & Evaluation).

Spatial experiences in route finding, such as the ability of finding low-traffic routes, exert a significant influence on travel time in big cities; therefore, the spatial experiences of seasoned individuals such as taxi drivers in route finding can be useful for improving route-finding algorithms and preventing using routes having considerable traffic. In this regard, a spatial experience-based route-finding algorithm is introduced through ontology in this paper. To this end, different methods of modeling experiences are investigated. Then, a modeling method is chosen for modeling the experiences of drivers for route finding depending on the advantages of ontology, and an ontology based on the taxi drivers' experiences is proposed. This ontology is employed to create an ontology-based route-finding algorithm. The results are compared with those of Google maps in terms of route length and travel time at peak traffic time. According to the results, although the route lengths of route-finding method based on the ontology of drivers' experiences in three cases (from nine cases) are greater than that based on Google maps, the travel times are shorter in most cases, and in some routes, the difference in travel time reaches only 10 minutes.

KEYWORDS
experience, knowledge, modeling, ontology, route finding

1 | INTRODUCTION

> Experience is composed of all the events that occur between sensation (i.e., an observer's awareness of an energy form impinging on a receptor physiologically designed to transduce it) and perception (i.e., the interpretation of the sensation), as well as memory (i.e., the subsequent organization and recall of such interpretations), which will have been modified and conditioned in the interim by many if not all of the prior and subsequent occurrences of this 'sensation, perception, interpretation, sequence [1].

The term "experience" has different meanings across different fields. For instance, in tourism, it is a constant flow of thoughts and feelings over the moments of your consciousness [2], and it occurs through complicated psychological, sociological, and cognitive interactive processes [3]. In the field of GIS, spatial experience is the ability of comprehending the relation between the real world's objects, spaces, and areas and can be acquired after several years of learning and experience by experts.

Taxi associations are one of the organizations facing the loss of expert experiences. On a daily basis, many taxi drivers retire, and their experiences are lost without transferring to the next driver. Consequently, new taxi drivers incur high cost of training and considerable time to gain the experience comparable to that

M. Barzegar and A. Sadeghi-Niaraki contributed equally to this work.

of previous drivers. Creating an ontology of such experiences and using it in route finding can be a good idea to store drivers' experiences in a system from which one can benefit in the future.

In this paper, a spatial experience-based route-finding algorithm was introduced using an ontology. Accordingly, many different methods of modeling experiences were investigated, such as semantic networks, rules, logic, and ontology. Subsequently, an ontology was presented to store spatial experiences for use in route finding. For this purpose, an ontology of drivers' experiences was first designed. Then, the routes of taxi drivers were collected using an application. These routes were categorized into traffic classes and non-traffic classes of experience ontology depending on departure time. Each route was saved as a separate owl class, including the segments of the routes of relevant individuals. Finally, the spatial experience-based route-finding algorithm was implemented using the ontology. The experiment details are described in the following sections. Section 2 describes the different methods of modeling spatial experiences. In Section 3, the experience modeling methods are compared with each other. Section 4 presents the details of designing spatial experience-based route-finding algorithm using ontology (SERFO). In Section 5, this algorithm is implemented in Tehran, Iran. Finally, Section 6 evaluates the proposed method, and Section 7 presents a general conclusion.

2 | MODELING EXPERIENCES

Several methods have been investigated by researchers from different fields for modeling experiences. Some of them include semantic networks, rules, logic, and ontologies. Given the research domain and requirements, a specific method can be used to model experiences and reuse them to solve different problems. Figure 1 shows a schematic view of the experience modeling methods, and Table 1 shows a brief comparison of these models and some papers using these methods.

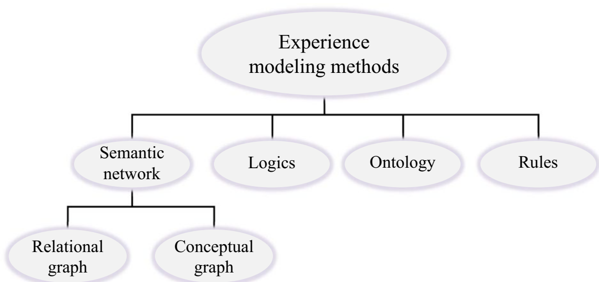

FIGURE 1 Experience modeling methods

Semantic networks can be used to model experiences. A semantic network is a graph wherein nodes indicate concepts, and edges show the relationships between them [17]. Two types of semantic networks can be used to show logic: relational graphs and conceptual graphs. Conceptual graphs were invented after relational graphs, and ontology integration is the main feature of these graphs. They create a uniform formulation for interactive requirements [4]. Some researchers used this modeling method in their studies. Foguem et al [4] used conceptual graphs for knowledge formalization in experience feedback processes and converted derived information from experiences to explicit knowledge. Kamsu-Foguem and Abanda [5] also used knowledge bases for collecting experiences and conceptual graph for representing ontology in the industry. In another paper, data mining and conceptual graphs have been used for reusing experiences in the industry [6].

Rules are another form of knowledge representation. Rules are expressed using if-then structures, and different types of complicated sentences can be expressed through them. The if part is also referred to as the body of a rule, and the then part is called the head. Generally, rule-based knowledge representation systems operate according to realities. They are formulated as a specific type of rule with an empty body [17]. This modeling method has been used by Park et al [7] in business processes and also by Reyes et al [8] for storing and reusing experiences in the industry.

Semantic networks and rules are formulated using logic to present accurate meanings. Without such accurate formulation, they are vague and problematic for computational purposes. The most well-known logical formulation of knowledge representation is the "first-order predicate calculus" or first-order logic. It is used to describe a domain as a combination of objects and creating logical formulae from these objects through predicates, functions, variables, and logical links [17]. Cheng et al used this method for creating a logic model for the epistemic process in scientific discovery and epistemic programming [12].

TABLE 1 Comparison of different experience modeling methods

Method of experience modeling	Features
Semantic network [4–6]	Modeling experience with a graph wherein its nodes are concepts and its edges are relationships among these concepts
Rules [5,7–11]	Representing knowledge of experiences with if-then rules
Logic [8,12]	Creating logical formulae from knowledge through predicates, functions, variables, and logical links
Ontologies [9–11,13–16]	Ontologies comprise a series of words and a set of rules through which words can be combined to model a domain

Ontology is the final method of modeling experiences. According to Webster's Dictionary, ontology is a branch of metaphysics related to the nature and relationships existing in it. In knowledge engineering, an ontology is a system comprising a series of words and a set of rules through which words can be combined to model a domain. Reference [18] provides the classic definition of ontology: "Ontology is the explicit and formal statement of the features of a shared conceptualization." In computer and information sciences, ontology is a valid nomination and definition of type, features, and relationships of the entities defined in a specific field. In fact, ontology classifies the variables required for a collection of computations and creates relationships between them. Some papers used this method in their works. Abel [13] proposed organized knowledge to be regard as ontology and investigated the role of knowledge in the organized learning process. In other studies, knowledge base [9], ontology [10], and web applications [11] have been used for exchanging experiences. In addition, Razmerita et al [14] proposed an ontology for modeling users in knowledge management systems. An ontology for businesses was proposed by Osterwalder and Pigneur [15] in order to enable knowledge sharing between companies. This ontology is composed of four key elements—product innovation, infrastructure management, customer relationship, and financial. Zhang et al [16] also proposed an ontology for construction safety and formalized knowledge relating to safety management. This ontology is composed of three domain models: product, safety, and process.

3 | COMPARISON OF EXPERIENCE MODELING METHODS

Ontology has numerous advantages, the first of which is sharing common concept of information structure among people or software agents [18,19]. For instance, if several different websites, each providing medical information or internet-based medical services create a similar ontology of the words that they use, computer agents can extract information from different websites and merge them. The merged information can be then used to answer user questions or used as an input for other applications. The second advantage is the possibility of reusing the knowledge of a field. If some researchers develop an ontology, others can use it in their field and/or for building a larger ontology. Then, several existing ontologies describing different parts of this large ontology can be merged [20]. The third advantage is the possibility of making explicit domain assumptions, through which assumptions can be changed if the domain knowledge is changed. If it is extremely complicated to code the assumptions, understanding and changing them will be difficult [20]. The fourth advantage is the possibility of separating domain knowledge from the operational knowledge. The configuration of a product can be described through its components according to a series of specific features and then implement an application that does the configuration regardless of the products and their components [21]. The fifth advantage is the analysis of the domain knowledge. When an existing ontology is to be reused, a formal analysis of words can be valuable [22]. Therefore, the use of an ontology can help benefit from previous experiences to solve new problems and share the experiences.

Regarding these advantages, semantic networks and rules are primarily used for knowledge representation and their applications are limited; hence, all relations between concepts cannot be presented by these modeling methods. Moreover, Lee [23] proposed some demerits for logical models of which one is complexity. Furthermore, these models are not explicit and modeling complex phenomena such as human activities, behaviors, and emotions is extremely difficult with these models and in some cases impossible. However, the relations defined in ontology are explicit and clear and everyone can understand these relations such as belonging. For example, Ni [24] modeled human activities and Smith [25] modeled human emotions with ontology. Moreover, ontology is a type of classification and has a hierarchical structure; thus, its basic concepts and structure is clear and understandable. In addition, logical models are less updatable because changing a logical relation can lead to changing the whole model. However, the ontological models are designed in a manner that allows them to be updated and this rule is a fundamental principle in designing these models. Consequently, in this paper, the taxi drivers' behaviors (experiences) are modeled by ontology.

4 | DESIGNING THE SPATIAL EXPERIENCE-BASED ALGORITHM USING AN ONTOLOGY

The main problem of route-finding applications is the relatively long time it takes to find the route between two nodes in addition to the large amount of data [26]. It is also necessary that the system provide a real-time response to user needs in every condition. The abovementioned problems prevent the services from operating in real time. In this paper, ontology was used to cope with such problems because it lets us reuse previous information without processing that helps services to operate in real time. Furthermore, as the data are saved as owl text files, the problem of excessive amount of data is resolved because saving the data as text files requires considerably less storage space than saving them in other formats. Table 2 shows a brief review of different studies in the field of ontology and route finding.

With regard to these types of research, the structure of the ontology that is proposed in this paper is different and the definition of ontology classes and their data properties are unique. For example, in some researches, negligible properties (such as road width that is constant in highways which are the most common roads used by drivers) that have an insignificant effect on the performance of route-finding algorithms are considered; however, in this paper, by defining classes and properties, more important properties such as the x and y coordinates are defined as data properties. Moreover, dividing classes to experimental and non-experimental routes and according to traffic were not performed in these papers and this is an evidence for the uniqueness of the conceptual view presented herein.

Generally, there are three steps in creating the ontology of drivers' experiences: designing the ontology, saving routes in the ontology, and retrieving routes from the ontology. In the first step, the schematic view of the ontology is designed. In the next step, data are classified as relevant classes according to this view.

In the step of designing an ontology, first, an ontology is created to store the routes of taxi drivers. This ontology includes two main classes of experimental and non-experimental routes. The class of experimental routes stores the routes of taxi drivers. This class includes two subclasses: traffic and non-traffic. The traffic class comprises the routes traveled at peak traffic times (7–10 AM and 4–8 PM). The rest of the routes are put into the non-traffic class of experimental routes class in the drivers' experience ontology. The nonexperimental routes class comprises the routes wherein their locations and destinations are not among the routes that are traversed by taxi drivers. They are obtained from a route-finding algorithm. In the owl file of the general ontology of drivers' experiences, only route names are defined as classes to improve upon processing efficiency and for simplicity. The individuals of routes are not defined in this file. For each route class, a separate owl file is defined. The file name and its class are similar to the corresponding route class name in the owl file of the general ontology of drivers' experiences. Each route segment is defined as an individual for the route class in the corresponding owl file of the route. The name of this individual is the corresponding route segment ID. The attributes of the x and y coordinates of the starting point of each route segment are defined as the data properties of individuals. Figure 2 shows a part of the general ontology of drivers' experience.

To store the routes of taxi drivers categorized as the class of experimental routes, first, it is determined whether the route is related to peak traffic times or non-traffic times. If the route is related to peak traffic times, the name of the corresponding class of route is defined as location_destination_t (t refers to traffic). Then, the corresponding class is defined as a subclass of the traffic class of experimental routes in the ontology of drivers' experiences. If the route corresponds to low traffic times, the class name is defined as location_destination, and the corresponding route is then defined as a subclass of the non-traffic class of experimental routes in the ontology of drivers' experiences. Considering that the name of the class is determined for each route, a separate owl file with the same name is defined for each route. This owl file also has a class with the same name. Each segment of the route is defined as an individual. The name of such an individual is defined using the ID of the corresponding segment. The attributes of the x and y coordinates of these route segments are defined as the data properties of relevant individuals.

To store the routes obtained from route finding, the name of the corresponding class is defined as location_destination first. Then, a subclass with the same name is determined in the class of non-experimental routes of the drivers' experiences ontology. Moreover, a separate owl file is defined with the same name to store the segments of this route. Similar to the process of storing an experimental route, the

TABLE 2 Different studies in the field of ontology and route finding

Ref.	Features
[27]	Using ontology in the field of personalized trip and animal life monitoring
[28]	Using ontology for predicating vehicle accidents
[29]	Using ontology for investigating the behavior of individuals in a mobile game. In this research, a series of georeferenced points are embedded on the ground. When the person connects to the game server, passes these points by answering some puzzles and as a result, a route will be generated that can be used to examine individual behaviors during the game
[30]	Combining path simulation with path ontology to simulate the angle and direction of airplane landing and flight and the flight path
[31]	Using ontology for identifying the abnormal routes in maritime transport to detect transportation contraband in maritime surveillance
[32]	Using ontology for investigating seals paths
[33]	Using ontology for analyzing city traffic
[34]	Using ontology for aiding SDI services, especially route-finding analysis
[35]	Proposing ontology-based route-finding system using multicriteria decision making
[36]	Proposing ontology-based conceptual modeling for navigation and tourism systems. This system is a multimedia system and spatial database that integrates with different sensors such as digital cameras and GPS in mobile environment and relates spatial-based services to context-based services to help context awareness services and applications in desktop and mobile environments

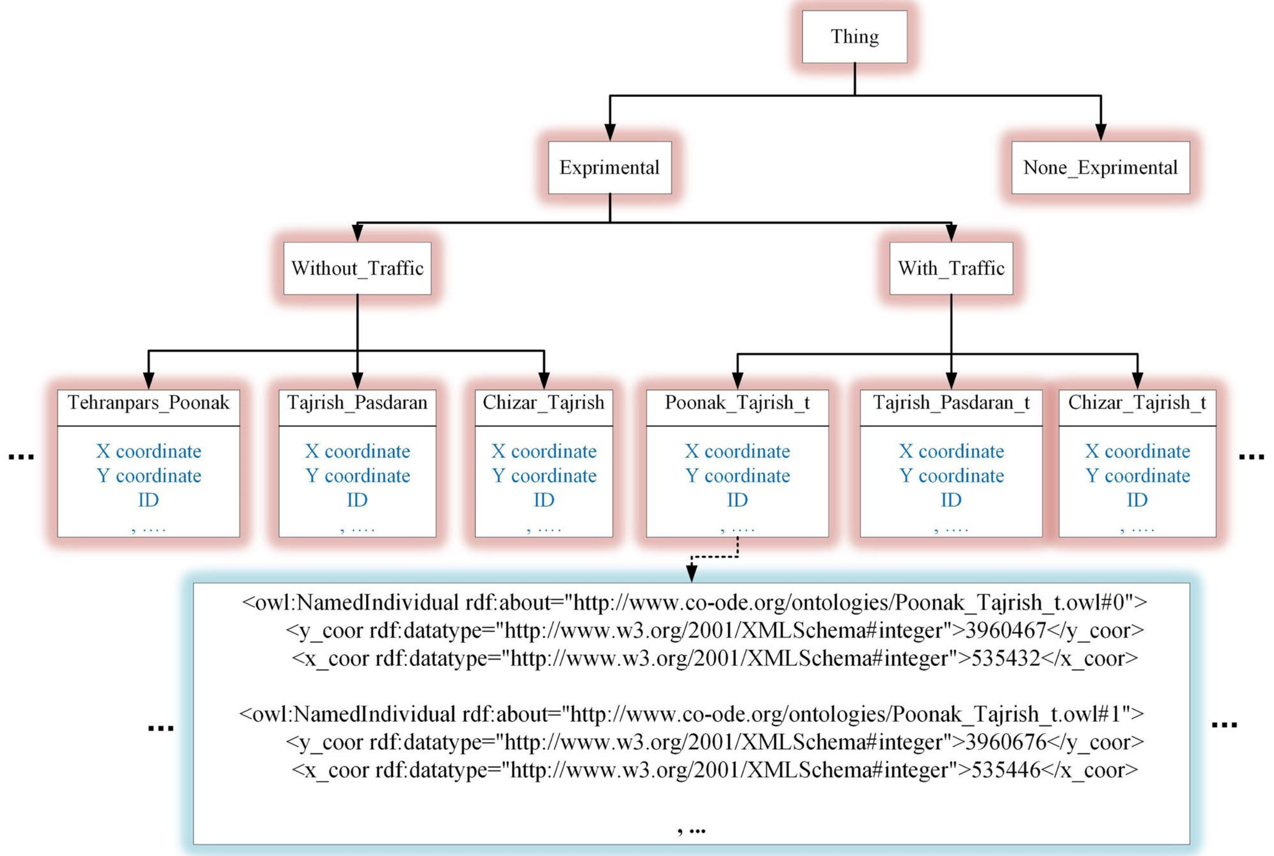

FIGURE 2 General drivers' experiences ontology (to save space, only a part of the routes is shown here)

class name defined in this owl file has the same name with a class defined in the ontology of drivers' experiences. Its individuals are the route segments obtained from route finding, and the ID of each segment is defined as the name of the corresponding individual. Furthermore, the attributes of the *x* and *y* coordinates are defined as data properties.

Figure 3 shows the proposed algorithm for route finding. To retrieve routes from the ontology of drivers' experiences in route finding, a user specifies the location, destination, and departure time first. Subsequently, it is determined whether there is a class with this location and destination in the ontology of drivers' experiences. If there is such a class, the route segments (individuals of this class) of the owl file of this route are retrieved and shown without processing. If there is no such class, it is first determined whether the location and the destination are present in the experimental routes. If the location and destination are present in the experimental routes, only the experimental routes are used to create the road network graph. If both do not exist in the experimental routes, the main road network is used to create the road network graph for route finding. After route finding, the name of the corresponding route is recorded as a subclass of the non-experimental routes class of drivers' experiences ontology so that if the user requests it, it can be retrieved without processing. The resultant route segments are saved as individuals of a class with the same name with the corresponding route in a separate owl file.

5 | SERFO ALGORITHM IMPLEMENTATION

In this paper, an ontology is created based on drivers' experiences and used for route finding. To implement the ontology of experiences, the required data are collected by writing an application in which OSM is used for saving taxi routes. This application is programmed in an Android environment and ARCGIS SDK for Android spatialite is used in this application. Thus, the routes are stored in the application as line format by clicking on the map for traffic and non-traffic times. Then, these routes are converted to shapefiles. Subsequently, they are preprocessed in ArcGIS and an experimental road network is created using these routes. Then, this road network and the main road network are saved in the Oracle database. In the next step, each route is converted into a separate owl file using the JAVA OWL API, and the segments of each route are stored as individuals. A general owl file is then created for the ontology of drivers' experiences using these routes in Protégé that contains only the name of the routes.

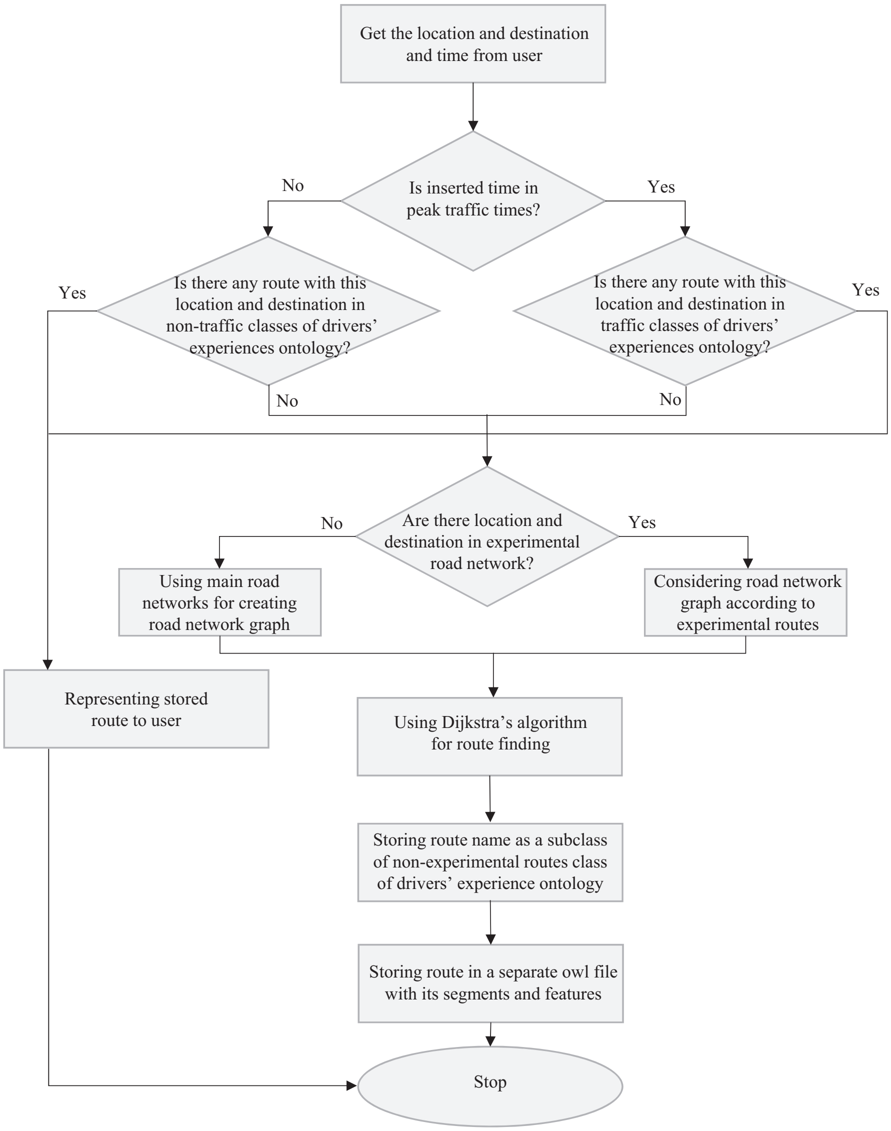

FIGURE 3 Proposed algorithm (SERFO)

For instance, if the route between Poonak and Tajrish is considered during traffic, this class is saved as a subclass named Poonak_Tajrish_t in the traffic class of nonexperimental routes in the drivers' experiences ontology. Then, a separate owl file named Poonak_Tajrish_t is created to save the segments of this route. This file comprises a class named Poonak_Tajrish_t, and each segment of the route, which should be traversed to reach Tajrish from Poonak at the peak traffic time, is defined as an individual. The name of this individual is defined using the ID of the corresponding route segment. The attributes of the x and y coordinates of each route segment are defined as the data properties of its individuals. Figure 4 shows the general procedure for route finding.

According to Figure 4, the ontology is used for route finding after its creation. If a new route is generated for each execution of the program that is not in the previous routes stored in the ontology, this route is defined as a class of drivers' experiences ontology, so that if a user requests it, it can be represented without processing. In other words, the segments of this class are stored as individuals of a class named location_destination or location_destination_t (in case the time of departure is in traffic hours) and is stored as a subclass of non-experimental class. For retrieving the routes from the ontology, a pellet reasoner is used as a reasoner and an owl reasoner is used as an interface for OWL API. This algorithm is implemented using Java in a desktop environment. Therefore, each route is saved as a low-size owl file, and the ontology is updated after each execution so that new routes can be added. As a result, processing data over time by executing the algorithm more often will not be necessary. Due to the low size of stored routes, the problem of excessive data storage is also resolved in the database because the size of each class after being saved as a separate owl file is nearly 1/4 or 1/5 that of a route shapefile. If the inserted location and

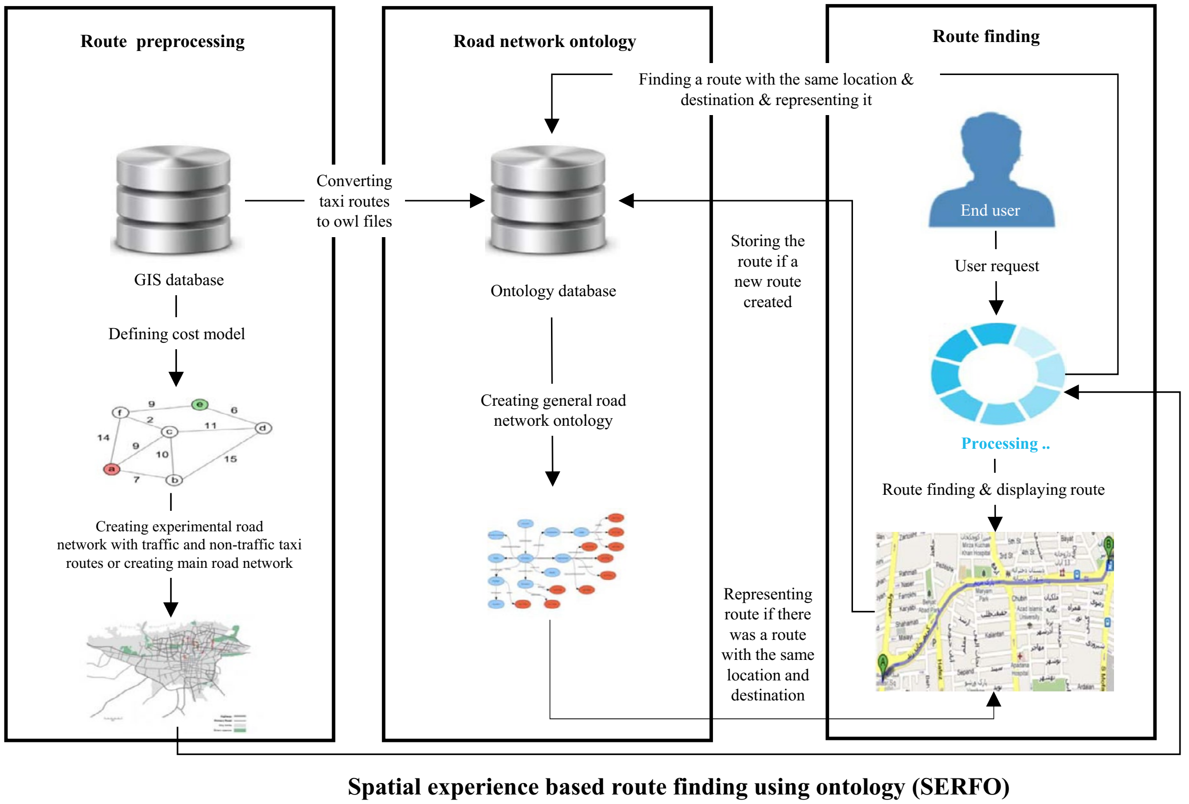

FIGURE 4 General procedure

destination do not exist in the experimental road network, the main road network and Dijkstra's algorithm are used to calculate the route. Figure 5 shows the results of route finding based on the drivers' experiences ontology and Dijkstra's algorithm for a location and destination pair.

6 | SERFO ALGORITHM IMPLEMENTATION

To evaluate the proposed method, nine pairs of different locations and destinations, covering approximately all of Tehran, are selected. Then, the ontology-based route-finding algorithm and Google maps are used to calculate the relevant routes for similar departure times. Due to the importance of accuracy and speed of route finding at peak traffic times, the departure time is selected at peak traffic times. The length of each route is calculated. The travel times for the proposed method are obtained from 10 drivers that traveled routes during peak traffic. After calculating the routes, in three cases, the routes of the ontology-based route-finding algorithm and Google maps were observed to be similar.

6.1 | Route length evaluation

Figure 6 shows the route length diagrams for the nine corresponding routes of the two methods. The route lengths for the proposed method are calculated by adding up the length of the route segments. Figure 7 indicates the ratio of the route length observed in the ontology-based route-finding algorithm to the route length observed through Google maps.

According to Figure 6, in three cases, the route lengths observed through Google maps are shorter than the route lengths observed in the ontology-based algorithm; in three cases, the route lengths of the ontology-based algorithm are longer than the corresponding Google maps route; in the remaining three cases, the route lengths of both methods are similar (because the routes are similar). According to Figure 7, the route length ratios of the ontology-based route-finding algorithm to the Google maps are close to one in eight cases. This ratio is close to 1.46 in only one case. Therefore, the route length of the ontology-based route-finding algorithm is similar or close to the route length observed through Google maps in most cases.

6.2 | Travel time evaluation

Figure 8 indicates the travel time diagrams for nine corresponding routes of the two methods. These times are obtained by several drivers that traveled routes during peak traffic. Figure 9 shows the ratio of travel time in the ontology-based route-finding algorithm to the travel time

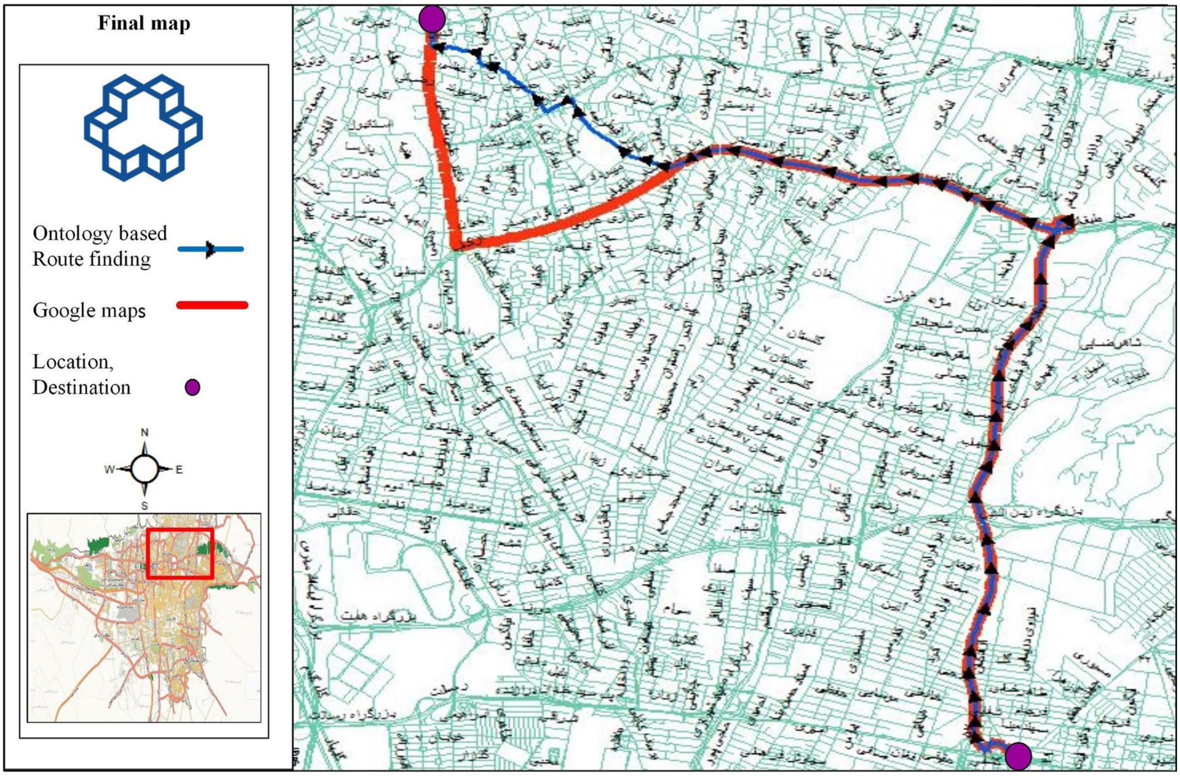

FIGURE 5 Derived routes for a location and destination pair (route number 2) using two methods

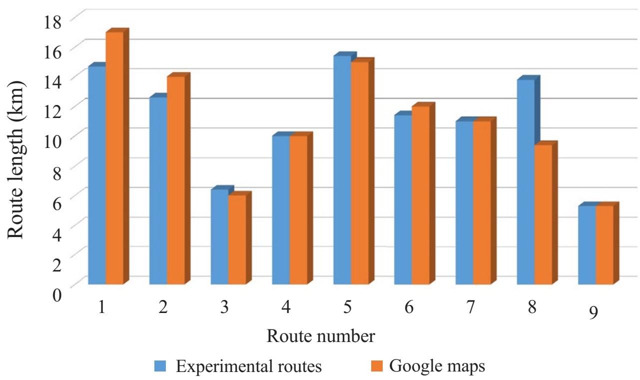

FIGURE 6 Comparison of route lengths of two methods for 10 evaluated routes during peak traffic

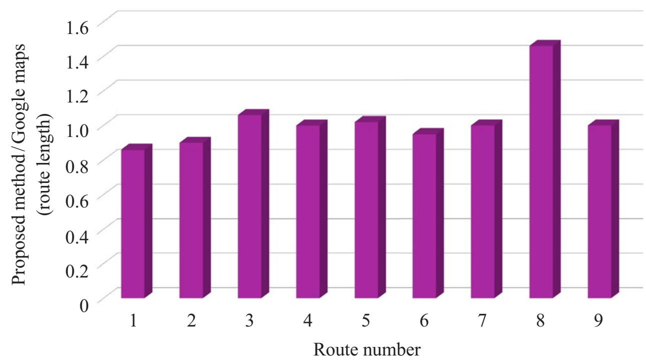

FIGURE 7 Ratio of the route length observed in the ontology-based route-finding algorithm to the route length observed through Google maps

observed through Google maps. Table 3 indicates the mean of travel times and route lengths for the nine selected routes.

According to Figure 8, in five cases, the travel times of the ontology-based route-finding algorithm are shorter than the travel time observed through Google maps; in four cases, the travel times for both methods are similar (in three cases, the routes are similar). Figure 9 shows that the ratio of travel time in the ontology-based route-finding algorithm to the corresponding Google maps time is smaller than 1 for five cases and is 1 for four cases. Therefore, the ontology-based route-finding algorithm resulted in a shorter travel time as compared with Google maps in most cases and the mean route length of this algorithm is shorter as well. The reason is that these routes have low traffic, and the speed of cars will be greater.

7 | CONCLUSION

Different individuals gain different spatial experiences. As there is no system for saving these experiences, they are discarded. This study lets researchers store spatial experiences and therefore make systems intelligent. In this paper, a spatial

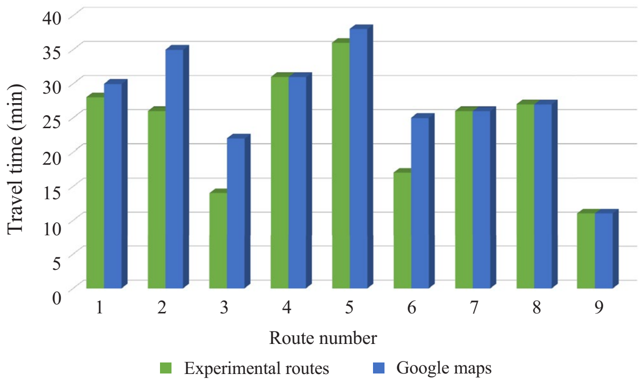

FIGURE 8 Comparison of the travel time for nine evaluated routes of the two methods during peak traffic

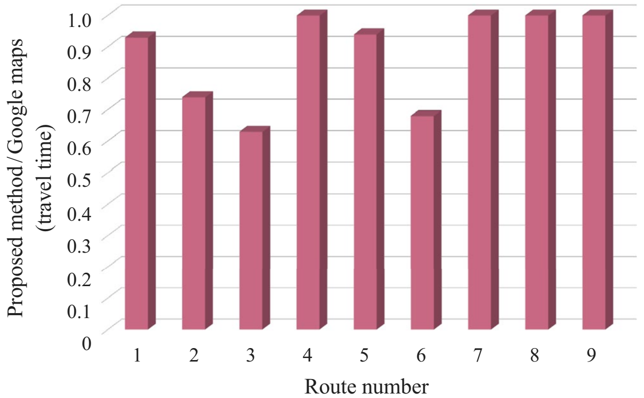

FIGURE 9 Comparison of the travel time in the ontology-based route-finding algorithm to travel time observed through Google maps

TABLE 3 Mean of travel time and route length for the two methods

Name of method	Google maps	Experimental algorithm
Mean of travel time (min)	27.22	24.00
Mean of route length (km)	11.17	11.07

experience-based route-finding algorithm was designed using ontology. Then, the ontology data were collected using the routes traveled by taxi drivers at peak traffic and low traffic times, and the route-finding algorithm was implemented in Tehran.

In the ontology-based route-finding method, if there is a route with the location and destination inserted by user in the ontology of experiences, the corresponding route can be represented without processing. If there is no such route, it is determined whether both the location and the destination exist in the network of experimental routes. If both the location and the destination exist in the network of experimental routes, only the experimental road network is used to create the graph for route finding. If they do not exist in the experimental road network, the main road network is used to create the road network graph and route finding. After route finding, the resultant route is saved as a separate owl file in the nonexperimental routes class of the road network ontology. If the same location and destination are requested, the stored route is instantly shown to the user without route finding. The difference between this algorithm and previous experimental route-finding algorithms is that our algorithm uses ontology and creates road networks only through experimental routes when both the location and the destination exist on experimental routes. The problem of excessive data storage space in the database is resolved by saving each new path as a low-size owl class. Furthermore, the use of ontology develops and updates the system after the implementation and generation of every new path, and the need for processing decreases. These two advantages help route finding become operational in real time. According to evaluations, although the route length is longer in some cases with this method in comparison with Google maps, the travel time is shorter in most cases.These results guarantee the appropriateness of adopting this method for route finding.

For further research, more diverse applications of modeling spatial experiences of individuals can be investigated. The experiences can be modeled for hospital emergencies, firefighting, tourism, among others. For instance, studies can be conducted on modeling experiences of experts who encounter many unpredictable incidents such as in hospital emergencies. Likewise, researchers can model the experiences of experienced firefighters who have encountered many fire events for future research purposes.

COMPETING INTERESTS

The authors declare that they have no competing interests.

ACKNOWLEDGMENTS

This research was supported by the MSIT (Ministry of Science and ICT), Korea, under the ITRC (Information Technology Research Center) support program (IITP-2019-2016-0-00312) supervised by the IITP (Institute for Information & communications Technology Planning & Evaluation).

ORCID

Abolghasem Sadeghi-Niaraki https://orcid.org/0000-0002-0048-8216

REFERENCES

1. S. Volo, *Conceptualizing experience: a tourist based approach*, J. Hospitality Marketing Manag. **18** (2009), 111–126.
2. R. A. Carlson, Experienced Cognition, Psychology Press, Mahwah, NJ, USA, 1997.

3. M. Kang and U. Gretzel, *Perceptions of museum podcast tours: effects of consumer innovativeness, internet familiarity and podcasting affinity on performance expectancies*, Tour. Manag. Perspect. **4** (2012), 155–163.
4. B. K. Foguem et al., *Knowledge formalization in experience feedback processes: an ontology-based approach*, Comp. Ind. **59** (2008), 694–710.
5. B. Kamsu-Foguem and F. H. Abanda, *Experience modeling with graphs encoded knowledge for construction industry*, Comput. Ind. **70** (2015), 79–88.
6. K. Efthymiou et al., *On knowledge reuse for manufacturing systems design and planning: a semantic technology approach*, CIRP J. Manuf. Sci. Technol. **8** (2015), 1–11.
7. C. Park et al., *Knowledge-based AOP framework for business rule aspects in business process*, ETRI J. **29** (2007), 477–488.
8. E. R. Reyes et al., *Improvement of online adaptation knowledge acquisition and reuse in case-based reasoning: application to process engineering design*, Eng. Appl. Artif. Intell. **41** (2015), 1–16.
9. D. Mourtzis, M. Doukas, and C. Giannoulis, *An inference-based knowledge reuse framework for historical product and production information retrieval*, Procedia CIRP **41** (2016), 472–477.
10. P. P. Ruiz, B. K. Foguem, and B. Grabot, *Generating knowledge in maintenance from experience feedback*, Knowl-Based Syst. **68** (2014), 4–20.
11. W. L. Mikos et al., *A system for distributed sharing and reuse of design and manufacturing knowledge in the PFMEA domain using a description logics-based ontology*, J. Manuf. Syst. **30** (2011), 133–143.
12. J. Cheng, A strong relevant logic model of epistemic processes in scientific discovery, Information modelling and knowledge bases XI, IOS Press, Washington, DC, USA, 2000.
13. M. H. Abel, *Knowledge map-based web platform to facilitate organizational learning return of experiences*, Comput. Human Behaver **51** (2015), 960–966.
14. L. Razmerita et al., *Ontology-based user modeling for knowledge management systems*, in Proc. Int. Conf. User Model., Johnstown, PA, USA, June 22–26, 2003, pp. 213–217.
15. A. Osterwalder and Y. Pigneur, *An eBusiness model ontology for modeling eBusiness*, in Proc. BLED Electron. Commerce Conf., Bled, Slovenia, June 17–19, 2002, pp. 1–12.
16. S. Zhang et al., *Ontology-based semantic modeling of construction safety knowledge: towards automated safety planning for job hazard analysis (JHA)*, Automat. Constr. **52** (2015), 29–41.
17. G. S. Stephan, H. S. Pascal, and A. S. Andreas, Knowledge representation and ontologies, Springer, Berlin, Heidelberg, 2007.
18. T. R. Gruber, *A translation approach to portable ontology specification*, Knowl. Acquis. **5** (1993), 199–220.
19. M. A. Musen, *Dimensions of knowledge sharing and reuse*, Comp. Biomed. Res. **25** (1992), 435–467.
20. N. F. Noy and D. L. McGuinness, *Ontology development 101: A guide to creating your first ontology*, Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880, Mar. 2001.
21. D. L. McGuinness and J. Wright, *Conceptual modeling for configuration: A description logic-based approach*, Artif. Intell. Eng. Des. Anal. Manuf. **12** (1998), no. 4, 333–344.
22. D. L. McGuinness et al., *An environment for merging and testing large ontologies*, in Proc. Int. Conf. Principle Knowl. Representation Reasoning, Breckenridge, CO, USA, Apr. 11–15, 2000, pp. 483–493.
23. P. L. Lee, *What's wrong with logic models*, LCSA: Occasional Paper no. 1, 2011, available: https://www.lcsansw.org.au/documents/item/210
24. Q. Ni et al., *A foundational ontology-based model for human activity representation in smart homes*, J. Ambient Intell. Smart Environ. **8** (2016), no. 1, 47–61.
25. B. Smith, *Logic and formal ontology*, in J. N. Mohanty and W. McKenna (eds.), Husserl's phenomenology: a textbook, University Press of America, Lanham, MD, USA, 1989.
26. J. Shen and Y. Ban, *Route choice of the shortest travel time based on floating car data*, J. Sens. **2016** (2016), 7041653:1–7041711.
27. Y. Hu et al, *A geo-ontology design pattern for semantic trajectories*, in Proc Int. Conf. Spatial Inform. Theory, Scarborough, UK, Sept. 2–6, 2013, pp. 438–456.
28. M. Effati and A. Sadeghi-Niaraki, *A semantic-based classification and regression tree approach for modelling complex spatial rules in motor vehicle crashes domain*, WIREs: Mining Knowl Discovery **5** (2015), no. 4, 181–194.
29. M. Baglioni et al., *An ontology-based approach for the semantic modelling and reasoning on trajectories*, in Proc. Int. Conf. Concept. Model., Barcelona, Spain, Oct. 20–23, 2008, pp. 344–353.
30. U. Durak, H. Oğuztüzün, and S. K. Ider, *Ontology-based domain engineering for trajectory simulation reuse*, Int. J. Softw. Eng. Knowl. Eng. **19** (2009), no. 8, 1109–1129.
31. E. Camossi, P. Villa, and L. Mazzola, *Semantic-based anomalous pattern discovery in moving object trajectories*, arXiv preprint arXiv:1305.1946, 2013.
32. R. Wannous et al., *Modelling mobile object activities based on trajectory ontology rules considering spatial relationship rules*, Modeling approaches and algorithms for advanced computer applications, Springer International Publishing, 2013, pp. 249–258.
33. T. Malgundkar, M. Rao, and S. S. Mantha, *GIS driven urban traffic analysis based on ontology*, Int. J. Manag. Inform. Technol. **4** (2012), 15–23.
34. A. Sadeghi-Niaraki et al., *Ontology based SDI to facilitate spatially enabled society*, in Proc. GSDI 12 World Conf., Singapore, Oct. 19–22, 2010, pp. 1–10.
35. A. S. Niaraki and K. Kim, *Ontology based personalized route planning system using a multi-criteria decision making approach*, Expert Syst. Applicat. **36** (2009), no. 2, 2250–2259.
36. S. Saeedi et al., *An ontology based context modeling approach for mobile touring and navigation system*, in Proc. Canadian Geomatics Conf. Symp. Commission I, ISPRS Convergence in Geomatics–Shaping Canada's Competitive Landscape, Calgary, Canada, June 15–18, 2010, pp. 1–7.

AUTHOR BIOGRAPHIES

Maryam Barzegar received her BSc in Geomatics Engineering and MSc in GIS Engineering from K. N. Toosi University of Technology, Tehran, Iran. She is currently a PhD candidate in Infrastructure Engineering at The University of Melbourne, Australia. She has been involved in several funded research projects at the national and international level in the field of GIS. Her current research focuses on the 3D spatial query and analysis. Other research interests include smart cities, 3D data models and spatial databases.

Abolghasem Sadeghi-Niaraki received his BSc in Geomatics Engineering and MSc in GIS Engineering from K. N. Toosi University of Technology, Tehran, Iran. He received his PhD in Geoinformatics Engineering from Inha University, Incheon, Rep. of Korea, in 2008. He is currently an assistant professor as well as an advisor of Iranian Vice-presidency for Science and Technology. Dr Abolghasem has over 10 years of teaching and research experiences across different universities both in Korea and overseas. He has developed a strong background in leadership, sustainability, and collaborative research in the area of science and technology using mixed research methodology between Iran and Korea. He has a strong publication record and has published various peer-reviewed research papers in different reputed international journals and international conference proceedings. His research interests include ubiquitous GIS, ubiquitous transportation, Ubiquitous Spatial Data Infrastructure (USDI), ubiquitous health, smart cities, Culture Technology, ontology, indoor positioning UAV, Augmented reality and Virtual reality.

Maryam Shakeri received her BSc in Geomatics Engineering from N.C.C University, Tehran, Iran, and M.Sc. in GIS Engineering from K. N. Toosi University of Technology, Tehran, Iran. She is currently a PhD candidate in GIS Engineering and an assistant teacher in the JKIP international course at the K. N. Toosi University of Technology. She has teaching experience across different universities in Iran. She has been involved in several funded research projects at the national and international level in the field of GIS. Her current research focuses on the application of ubiquitous GIS and augmented reality. Other research interests include Ubiquitous Spatial Data Infrastructure (USDI), smart cities, Culture Technology, ontology, and virtual reality.