Landmark-based Navigation System for Mobile Devices Have No Built-in GPS Receiver and Compass

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ABSTRACT

When users are roaming in real-life environment and looking for specific place for learning (e.g., Gothic architecture) or fun (e.g., Bar Tour for the happy hour), it is important for them to have a guidance from the map, the people, and may be the mobile phone! This research aims to design a navigation system on mobile devices for users doing mobile learning activities. Two issues are needed to be taken into consideration: (1) in the real learning environment such as national park or zoo, sometimes there is no road or no named road, and (2) not all mobile devices have built-in GPS receiver and compass and even the devices have GPS receivers, sometimes, it can not receive GPS signals due to the weather issue or the user is inside a building (e.g., museum). This research designs the navigation system based on the spatial relations of objects and landmarks. This system allows users doing learning activities in the real world with their mobile devices directly and no needs to purchase a new one or concern if it has built-in GPS receiver/compass.

Author Keywords

GPS, Location-Based Service, Mobile Phone, Landmark

INTRODUCTION

In the mobile learning environment, the users could receive the learning materials provided by the system wherever they are located (Wu et al., 2010). Users spend time for moving in the real world environment and time for learning the related knowledge of the learning spot. Users will have much more time in learning if they can find the learning spot immediately. Hence, a good navigation system can lead students to the right learning spot more quickly. Many positioning technologies can be used to develop location-based learning services on mobile devices, including GPS, two dimension code (e.g., QR Code), active/passive RFID and so on.

Priestnall and colleagues (2009) have evaluated five techniques for augmenting the visitor experience include pre-generated acetate, bespoke PDA application, multimedia on mobile phone, Google Earth on tablet PC, and head-mounted VR display. They have found that similar stability issues such as GPS connectivity in the five techniques do make applications perform badly. Lu and colleagues (2010) adopt QR Code to help users tell the mobile learning system where they are and to make users identify the learning objects required by the system inside buildings. However, it may not easy to establish such authentic environment fully with QR Code and RFIDs due to it maintenance and equipment cost. This research proposes a mechanism to guide users moving from one place to another in the real world with guidance messages just like the driving guidance systems in cars.

This paper is organized as follows. Section 2 introduces the research works related to spatial relations and landmarks. Section 3 describes the theory and the design of situated map in which the spatial relationships of objects can be stored. Section 4 focuses on the guidance message generation process and Section 5 talks how the proposed navigation system can be used in mobile learning. Section 6 describes the experiment plan, and at the end, Section 7 concludes this research and discusses the issues needed to be solved for next.

RELATED WORKS FOR DESIGNING LANDMARK-BASED NAVIGATION SYSTEM

Spatial Knowledge

Mohan and Kashyap have proposed an object-oriented model for representing the spatial knowledge in tree form (Mohan & Kashyap, 1988). All the objects in the real world can be represented in hierarchy form as Figure 1 shows. In Figure 1, the object o_2 is one component of o, and o_2 comprises o_{21} and o_{22} in the spatial knowledge structure. There are two benefits of using object-oriented representation to store the spatial knowledge: (1) it is easy to describe the relations among objects; and, (2) the structure could be changed to various forms depending on user's requirement.

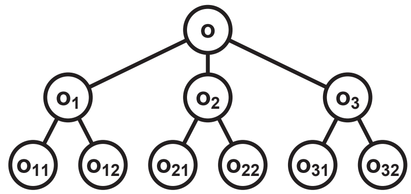


Figure 1. Spatial structure hierarchy (Mohan & Kashyap, 1988).

Del Bimbo has discussed about spatial relationships in geometry and he has classified the relationships into directional relationships and topological relationships (Del Bimbo, 1999).

- Directional relationships: A directional relation could be either in front of, back of, right, left, east, west, south, or north. All of these presentations are very general form of semantic. Directional relationships always stored in an array and the distance relationships between two objects are also stored in array.
- Topological relationships: Egenhofer and Fransoza have proposed a 9-intersection spatial model (Egenhofer & Franzosa, 1995). The 9-intersection model involves 29 topological relationships. Figure 2 shows an example about the operation of 9-intersection spatial model. There are three attributes for each object: Boundary, Interior, and Exterior. The matrix contains nine-intersections for object A and B. The left part of Figure 2 shows the situation of object A and B. For examples, because A's boundary touches B's boundary, hence, the value from A'b to B'b is 1; however, A's boundary doesn't intersect with B's interior, hence, the value from A'b to B'i is 0.

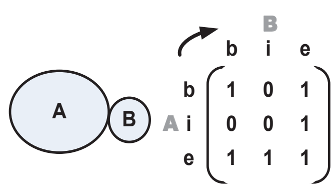


Figure 2. Topological relationships between object A and B (Egenhofer & Franzosa, 1995).

The 29 topological relationships can be categorized into eight categories, including "DISJOINT", "MEET", "INSIDE", "EQUAL", "CONTAINS", "COVERS", "COVERED BY", and "OVERLAP".

Landmarks

There are three basic elements to guide a human being moving in the real world: orientation, actions, and landmarks (Tversky & Lee, 1999). Orientation is the direction which helps people to know what direction he/she should go; actions give instructions to people and ask them to do some thing to reach the destination, such as turn left and straight forward; and, landmark is the essential thing to human to find way out, might more important than orientation (Golledge, 1999). Landmarks help people to organize space, and also give people as the reference in the world. Sorrows and Hirtle have proposed three landmark categories, visual, cognitive, and structure, each landmark category affects navigation method (Sorrows & Hirtle, 1999).

"Landmark Spider" is proposed by Caduff and Timpf (Caduff & Timpf, 2005), the landmark will be selected according to salience, distance, and orientation. Figure 3 illustrates the three characteristics between current position and the landmark. Salience is considering the obviously degree of landmark; distance is how far from current position to landmark; and orientation is the angle between current direction and the direction of landmark. This research uses a weighting function to select landmark, a, b and c are flexible according to users' needs: w_i = a*orientation + b*distance + c*salience.

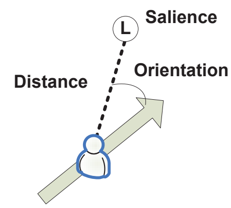


Figure 3. Salience, distance and orientation in landmark spider (Caduff & Timpf, 2005).

SPATIAL STRUCTURE IN THE REAL WORLD

The research goal is generating the guidance messages for users according to where they are at and the position of the learning spot in the real world. The guidance message is different from the traffic navigation message with GPS, because there are less obvious routes to users in the mobile learning environment such as zoo and museum than people driving or walking in the city. For instance, there is no named road like Jasper avenue or 13th street inside the park and the museum, so the system can not generate messages like "turn left on Jasper avenue" and "stop at the intersection of 13th street and 57 avenue".

Elements and Representation of Situated Map

In order to give the users moving instructions and lead them to somewhere they wants/needs to go, the spatial information should be known first. The spatial information is, for examples, the moving direction, related landmarks, and the distances. The most important is to know what landmarks that users can refer during their movement, such as a statue or a high building. This research designs a knowledge structure, *Situated Map*, to store the spatial information and the object relationships.

Situated Map (S-Map for short) is transferred from the real world maps with two elements: *Situated Axes* (denoted as AXE) and *Situated Objects* (denoted as o_i). Figure 4 shows a real map and the correspondent S-Map with two situated axes and many situated objects. The situated axes can be one dimension (timeline), two dimensions (real world 2D map), three dimensions (real world 3D map), and even more dimensions. All the situated objects on the S-Map are according to their (x, y) positions in this case, for example, the situated objects such as statue, sidewalks, and gardens, in the school campus.

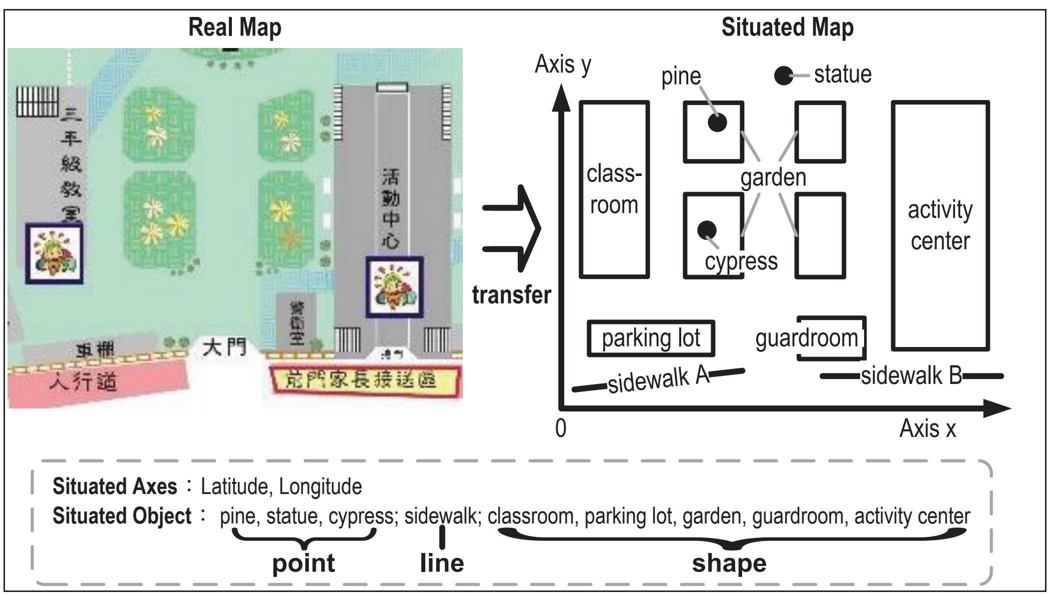


Figure 4. Real school campus map and the correspondent S-Map.

The objects on real map might be various, there are three major object types in S-Map: point (denoted as t_{point}), line (denoted as t_{line}), and shape (denoted as t_{shape}). The representation of the position is different to different object types in S-Map: the position of situated point object is (x_1, y_1); the position of situated line object is $\{(x_1, y_1); (x_2, y_2)\}$; and the position of situated shape object is $\{(x_1, y_1); (x_2, y_2); (x_3, y_3); (x_4, y_4)\}$.

Beside the situated object type and object position, situated objects have other attributes suchlike name and landmark flag. There is an additional attribute for the situated point object, i.e., learning object flag, this attribute is used to indicate whether the point object is a learning object or not. Taking all attributes into consideration, a situated object is, o_{name} (type; position; landmark flag; learning object flag).

Spatial Relationships among Objects

The guidance message can not be generated with only the coordinates and the situated object types. Users might have no idea about the coordinates and directions in the real worlds, for instance, no one can tell the latitude and the longitude that s/he is at and few people can point (either real or magnetic) North direction out in cloudy day. Things that users might only know are the rough distance, relative direction (i.e., left-hand side of the entrance), and the names of the object that they can see. In order to generate appropriate guidance messages for navigation purpose, the spatial relationships include distances, relative directions, and topological relationships among situated objects have to know first. There are four relative directions: Front, Back, Right, and Left.

S-Map only consider five topological relationship categories in the 9-intersect spatial model: *DISJOINT*, *CONTAINS*, *INSIDE*, *COVERS*, and *COVERED BY*. Table 1 lists all possibilities of the directional relations and topological relationships that two situated objects may have.

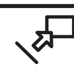
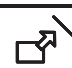
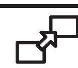
Figure	Directional Relations	Topological Relationships	Figure	Directional Relations	Topological Relationships
	Front, Back, Right, Left	DISJOINT		Front, Back, Right, Left	DISJOINT, INSIDE, COVERED BY
	Front, Back, Right, Left	DISJOINT, INSIDE, COVERED BY		Front, Back, Right, Left	DISJOINT, CONTAINS, COVERS
	Front, Back, Right, Left	DISJOINT, INSIDE, COVERD BY		Front, Back, Right, Left	DISJOINT, CONTAINS, COVERS
	Front, Back, Right, Left	DISJOINT		Front, Back, Right, Left	DISJOINT, CONTAINS, COVERS
	Front, Back, Right, Left	DISJOINT			

Table 1. Directional and topological relationships that two situated objects may have

S-Map can transform the topological relationships among situated objects to a tree-like form as Figure 5 shows. The transforming method is based on topological relationships among objects, the contains/inside and covers/covered by topological relationships in particular. If the situated object A contains or covers B, then the situated object A will be the parent node of B. On the contrary, if A is inside or covered by B, then the situated object A will be the child node of B.

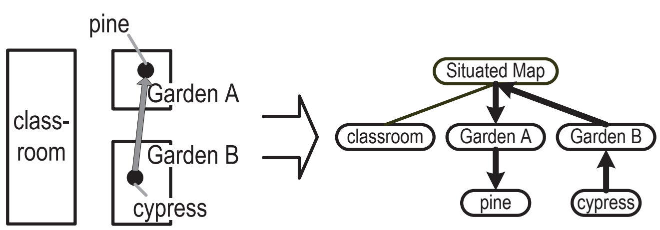


Figure 5. Tree-form S-Map.

Real World Movements and Situated Map Operations

Users move from one position to another in order to learn something or get close to the destination they want/need to go. The S-Map operations can be used as the movement indicators. On the left-hand side of Figure 5 represents a movement that users move from the cypress tree in garden B to the pine tree in garden A. Mapping such movement to the S-Map on the right-hand side of Figure 5, three S-Map operations, *Out*, *Move*, and *In*, are involved as Figure 6 shows. The Out-operation is from a child node to its parent node; the Move-operation is a transfer between two situated objects at the same level; and, the In-operation is a movement from a parent node to its child node.

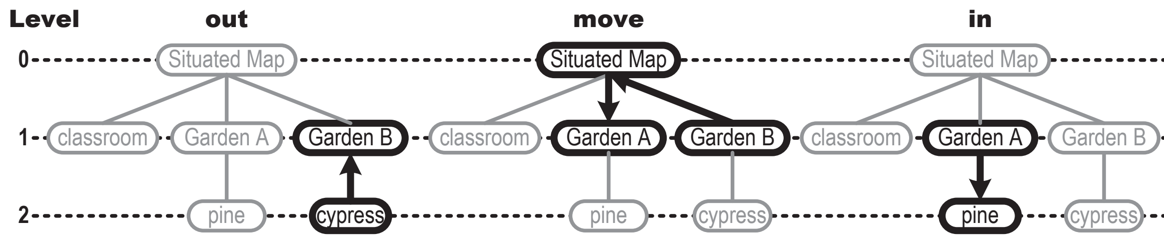


Figure 6. Three operations in S-Map.

NAVIGATION RULES AND GUIDANCE MESSAGE GENERATION

The guidance messages should consider the relative direction and distance between starting place and the destination as well as the objects that the users may encounter during the movement. The objects that users may see during their movement are so-called landmarks. Before giving a user movement instruction, it is important to know which direction the user faces, that is the orientation. It is important because that the user might see nothing if s/he heads to the wrong direction. So the navigation should also ensure that the user's orientation is correct. The navigation system can use the landmark to adjust the user's orientation, e.g., the first guidance message for the user is asking the user to make the landmark in front of his/her eyes.

Landmark Selection

The landmarks used in the guidance messages are also situated objects and can be picked-up from S-Map. The situated object might be a landmark candidate depends on the S-Map operations, taking situated objects in Figure 7 as examples: (1) in the Out-operation, movement from object D to object C, the situated objects which have the same parent object (e.g., object G) are landmark candidates; (2) in the Move-operation, movement from object C to object B, the situated objects which have the same parent object (e.g., object A and H) are landmark candidates; (3) and, in the In-operation, movement from object B to object E, the situated objects which have the same parent object (e.g., object F) are the landmark candidates.

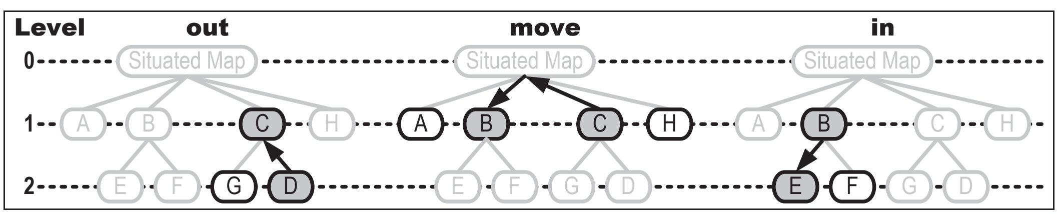


Figure 7. The landmark candidates (i.e., white boxes) in different S-Map operations.

Another issue needs to be solved before generating guidance messages is what landmarks can be used. A guidance message with landmarks makes users move in the real world easier, because users can know where they are and where they need to make a turn according to the landmark that they can recognize during their movements.

As abovementioned, the landmark is also a situated object and has its type, so the users will need to take different action when they encounter different landmark in real world. It makes a lot of sense, for instance, if the landmark is a pond, the users couldn't trespass it directly.

Point type landmarks

The situated point object is very common in the real world. In this research, the situated objects which are not related to the learning topic that the users are studying or are learning topic relevant objects but have been learned by the users are taking as landmark candidates. Figure 8 shows a route segment involves the starting place, the destination, and a point type situated object as landmark.

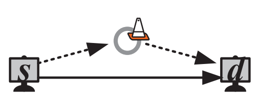


Figure 8. Point type landmark.

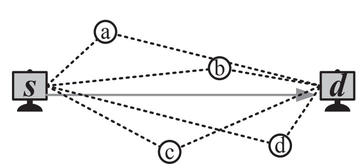


Figure 9. The point type landmark candidates.

Because the point type landmark is quite common in the real world, it is very important to make sure the chose landmark is the best choice. A good point type landmark should save users' time to travel and should be close to the original way to the destination that users currently walking on. This research calculates the angle between two straight lines: the line from the starting place to the landmark and the line from the landmark to the destination. The larger angle the two straight lines have the total distance is shorter. Figure 9 shows four point type landmark candidates, a, b, c, and d. The angle of landmark candidate b is the largest, therefore landmark b is chosen as the landmark.

Line type landmarks

When choose a situated line object as landmark, the navigation system needs to consider if an intersection happened between the line object and the original way towards to the destination that the users are currently walking on. As Figure 10 shows, the navigation system will choose the landmark candidate at right-hand side as the landmark due to it can tell the users "keep walking until you reached the intersection of Jasper Avenue".

Figure 10. The line type landmarks.

Shape type landmarks

The situated shape objects can be the landmarks. Figure 11 shows that a shape object can be either trespass-able or no-trespassing when users move from the starting place to the destination. The shape object which is trespass-able suchlike park and plaza as the left-hand side of Figure 11 shows. On the contrary, users will need to make a detour to pass the no-trespassing situated shape object clockwise or anti-clockwise. However, users may have no idea of when they should stop walking around the no-trespassing situated shape object. In order to save users' time and make sure that users do keep moving on the same orientation, this research only chooses the trespass-able shape objects as the landmarks.

Figure 11. The shape type landmarks.

If there are many landmarks found in a single S-Map operation, the priority is shape type landmarks > line type landmarks > point type landmarks.

Guidance Message Generation

Users will receive the guidance message which includes the movement from (temporary) starting place to the landmark and the landmark to the (temporary/final) destination. Besides the (temporary) starting place, landmark, and the (temporary/final) destination, the guidance message also contains three instructions: *Direction Instruction*, informs users about what the relative direction they should face to, suchlike right, left, forward or back; *Distance Instruction*, tells users how far they should move, suchlike two meters; and, *Action Instruction*, instructs students what to do when they get arrived at the landmark or the (temporary/final) destination, such as arrive, find, pass over, cross, and meet the periphery.

The guidance message for users moving from (temporary) start point to the landmark therefore looks like:

> *your are at {(temporary) starting place} now, please turn {Direction Instruction} and walk about {Distance Instruction} until {Action Instruction} {the landmark}.*

The guidance message for users moving from the landmark to the (temporary/final) destination looks like:

> *please turn {Direction Instruction} and walk about {Distance Instruction}, you will find { the (temporary/final) destination}.*

PROPOSED NAVIGATION SYSTEM AND GUIDANCE MESSAGES IN MOBILE LEARNING

In general, the mobile learning flow is: at beginning, students study out of classroom and observe leaning objects; then they move to next learning spot when they completed the study there; and, repeat above steps until they finished all learning tasks. The proposed navigation system can then be integrated into the flow as Figure 12 shows.

At step 1, teacher builds the situated map according to the learning environment suchlike school campus; at step 2, the navigation system transform the situated map into tree-form situated map; at step 3, the system picks those situated objects can be learned by students from the situated map and offers these objects to them; at step 4, students choose the learning object they want and/or need to learn; finally, at step 5, the system generates the guidance messages to lead students studying in the real world.

Here is a simple example when Alex studies plants in the school campus. Figure 4 shows the school campus map. There are six situated objects in the campus: Garden A, Garden B, sprinkler in Garden A, pine tree in Garden A, cypress tree in Garden B, and another sprinkler in Garden B. Assuming Alex just finished the observation activity of the cypress tree in garden B and is going to learn the pine tree in garden A as Figure 5 shows. Figure 6 shows the three route segments and its S-Map operations. With the landmark analysis and guidance message templates, the navigation system then can generate the following guidance messages one by one:

1. The S-Map operation of the first route segment is "out", the landmark is sprinkler (point type) in garden B. The guidance message is

Please turn {right-forward} and walk about {1.7 meters} until arrive {sprinkler}. Turn {right} and walk about {0.5 meter}, you will find {the edge of garden B}.

2. The S-Map operation of the second route segment is "move", there is no landmark in this route segment. The guidance message becomes

Please turn {left} and walk about {1 meter} until arrive {the edge of garden A}.

3. The S-Map operation of the third route segment is "in", the landmark is sprinkler (point type) in garden A. The guidance message is

Please turn {right} and walk about {0.5 meter} until arrive {sprinkler}. Turn {left-backward} walk about {1 meter}, you will find {pine}.

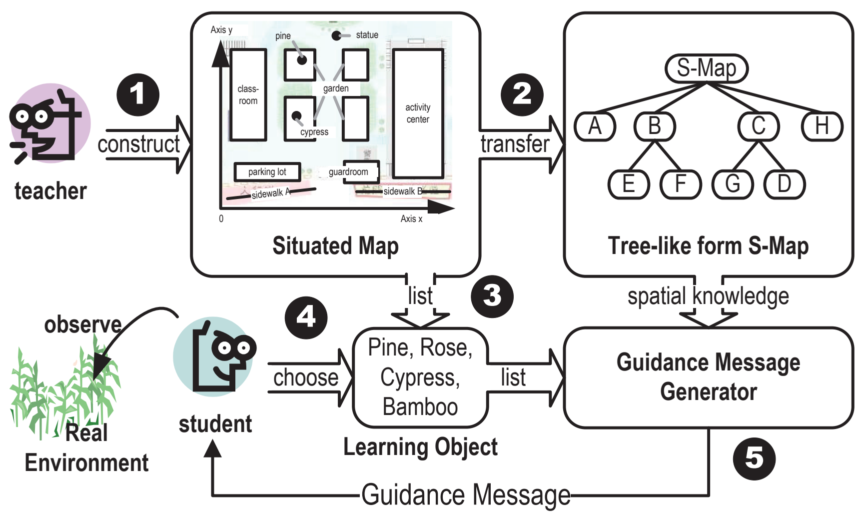


Figure 12. Proposed Navigation System in Mobile Learning

EXPERIMENT PLAN

The goal of this research focuses on how to generate guidance messages on the mobile devices have no built-in GPS receiver and compass as well as to guide users moving in the cloudy days and inside buildings. There is no experiment yet. However, an experiment plan is discussing and working on by researchers and teachers now, and the experiment is expected to do in this October. There will be 12 five-grade elementary school students (around 11 years old) in one class, and the experiment course will be biology and mainly focuses on the plants in the school campus. The course objective is teaching students plant shapes and organs, such as flowers, fruits, and seeds.

The experiment involves six steps:

1. Checking students' cognitive levels via pre-test and their past learning performances;
2. Choosing 3 different cognitive levels students and forming a small-group. There are two small-groups in both control group and experiment group;

3. Lecturing with traditional way in classroom;
4. Every small-group chooses their learning objects after school;
5. The small-group students in control group will do mobile learning without any guidance messages and the small-group students in experiment group will receive guidance messages during learning;
6. Finally, students need to have interview individually with teaching assistants.

Two goals of this experiment are: (1) does the guidance message human-readable? (2) does the guidance message could save student's time in travelling and searching learning object? The students in the same class are divided into two groups, the control group and the experiment group. The teaching assistant will accompany with the groups and record the time that each group spend on moving and searching specific learning object.

CONCLUSIONS

Mobile and wireless technologies make students learn the concepts and knowledge in the real world. However, with such ubiquitous learning model, students not only need to spend time to learn but also need to spend time to move and search the learning objects. The learning system should aware the context in the learning environment and lead students learning according to their locations. Although such location-based service can be well-implemented on GPS-enabled mobile devices such as iPad and Google Phone, two widely seen scenarios make things complicate. First of all, not all mobile devices have built-in GPS receiver and compass, e.g., eBook and most of regular mobile phones. Second, even a mobile device has built-in GPS receiver, the student might still encounter difficulty in using LBS services in many places and conditions, e.g., in the valleys, in the tunnel, inside museum, and at cloudy days. This research designs a landmark-based navigation system to lead students learning in the real world with those mobile devices have no built-in GPS-receiver and compass.

The navigation system currently only considers the relations among situated objects and doesn't take shortest path planning into consideration. Students might still need to spend long time to travel and search, because the system choose the path from one learning spot to anther based on if it is easy to navigate rather than distance. Beside *the shortest path issue*, this research simplified the problems by ignoring the curviform line objects and non-quadrilateral shape objects. How to transform these specific objects into the situated map is a big issue, which is *the object shaping issue*. Furthermore, this research also chooses to not take the no-trespassing situated shape objects as the landmarks. So how to inform users make a suitable detour to pass the no-trespassing situated shape object under the situation that the mobile devices have no location-aware feature is another issue, which is *the no-trespassing object issue*. At last, the geographical information should also be taken into consideration, because the landmarks might not be able to see by users due to its positions, heights, and even shapes, i.e., *the visibility issue*.

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