# Two Perspective Systems Using a Route as a Reference Object

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## Abstract

This paper discusses the spatial configuration between *objects* and a *route* which an agent follows according to instructions in a navigation task. We claim that a route can be regarded as a reference object and thereby two types of perspective system are defined; *the route-centered perspective system* and *the position-centered perspective system*. The route-centered perspective system is presented to partition a space by regarding a route as a boundary line. The position-centered perspective system is introduced to determine the spatial configuration between *objects* and the *positions on the route*. These perspective systems can explain the human mental mechanism of the dialogue.

### Keywords

navigation system, route description, perspective system, human spatial cognition

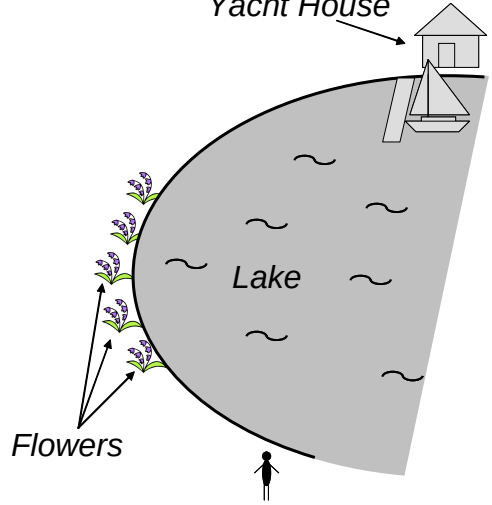
## Introduction

Research of *perspective systems*, which defines the spatial configuration between objects, is regarded as fundamental navigation systems [2]. This paper discusses the spatial configuration between *objects* and a *route* which an agent follows according to instructions in navigation tasks. Our claim is that a route, which used to be disregarded, can be a reference object. We define two types of perspective systems.

In cognitive studies, four perspective systems have been presented; the intrinsic, deictic, extrinsic, absolute perspective systems [8, 4, 5, 6, 3]. These perspective systems define a spatial configuration between objects by setting the axes on a reference object. However, the following cases are beyond the scope of the conventional studies of perspective systems since the spatial configuration in these cases cannot be described as a relation between objects.

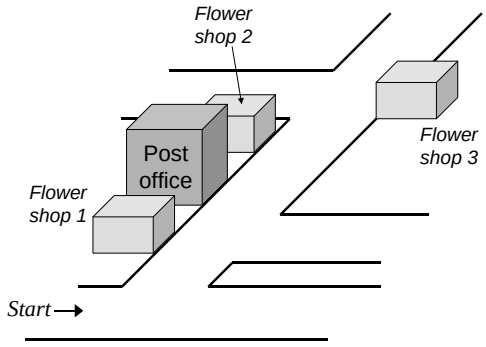
**(Case 1)** Consider the situation where an agent heads for a yacht house according to an instruction 'Head for the yacht house. You can see flowers on the right hand' (Figure 1). In the conventional perspective systems, the spatial configuration 'flowers on the right hand' cannot be explained because there is no reference object such as the pavement, rivers, desks etc.

**(Case 2)** Consider the situation where an agent receives an instruction '*On the right, you can see a flower shop*' (Figure 2). In this case, the instruction '*On the right*' has no reference. In the studies of real-time navigation, the planner is assumed to give instructions to the agent at the agent's current position on the route. Therefore, the instruction *'On the right'* is regarded as *'On the right at your current position'* [7, 2]. When the agent stands at the doorway from inside of the post office, he/she can interpret the instruction 'On the right' as 'On the right *of*




*Head for the yacht house. You can see flowers on the right hand.*

Figure 1: Case 1: The scenery by the lake




*Turn left at the crossing. On the left side there is a post office. Get me a stamp there. Then on the right, you can see a flower shop.*

Figure 2: Case 2: Ambiguity of reference "flower shop" in the world and an instruction

*the post office*' and head for the flower shop 1 as the planner expects.

In another case where instructions are given in advance (e.g., non real-time navigation), an agent can head for the flower shop 3 by interpreting the instruction 'On the right' as 'On the right *at the crossing where the agent turned left*.' This case shows that a reference object of the instruction is not only the agent's current position but also the agent's positions on the route. The conventional perspective systems, however, disregards the spatial configuration between an object (a flower shop) and the agent's position (the crossing the agent turned left).

## Route/Position-Centered Perspective Systems

To explain the mental mechanism of the agents exemplified by the above cases, the notion of the route should be taken into consideration. We propose two types of perspective systems: *the route-centered perspective system* and *the position-centered perspective system*. The route-centered perspective system is presented to partition a space by regarding a route as a boundary line. The position-centered perspective system is presented to determine the spatial configuration between *objects* and *the agent's former position*. Furthermore these two systems adopt an imaginary reference object; the route in the route-centered perspective system and the agent's positions on the route in the position-centered perspective system. Each case (the case 1 and case 2) can be explained by these two perspective systems respectively.

### The route-centered perspective system

In the route-centered perspective system, the reference object is a route (e.g., an *imaginary* line to the destination). By setting the route on a space, the space is partitioned into the right and the left along the route (Figure 3). By adopting the route-perspective system, the route can be regarded as the reference object of the instruction 'on the right hand' (i.e., on the right hand of *the route*), and the space is partitioned into the right and the left along the route.

### The position-centered perspective system

As mentioned above, the position-centered perspective system adopts an agent's former position on the route as a reference object. In our previous work [1], the agent's former position on the route is defined as *an action vector*[1]. Action vectors are the agent's former positions on the route where he/she turned, stopped or perceived the surroundings to fulfill his/her missions (e.g., to buy a stamp). Namely, the action vectors are accumulatively set on the route as the agent executes an instruction. Thus, we discriminate between the action vector and an imaginary point which can be set according to an arbitrary choice. In the case 1, after the agent has executed the instruction 'On the left, there is a post office. Get me a stamp there,' the action vectors are set on the doorway from inside/outside of the post office. Actually in the case 1, four action vectors can be set on the route (the crossing before/after the agent turned left and the doorway from inside/outside of the post office)(Figure 4).

Each action vector has a front-back axis and a right-left axis and these axes can determine the front-back and/or the right-left region of a world. Thus, a world is parti-

[1]For further details about action vectors, see [1].

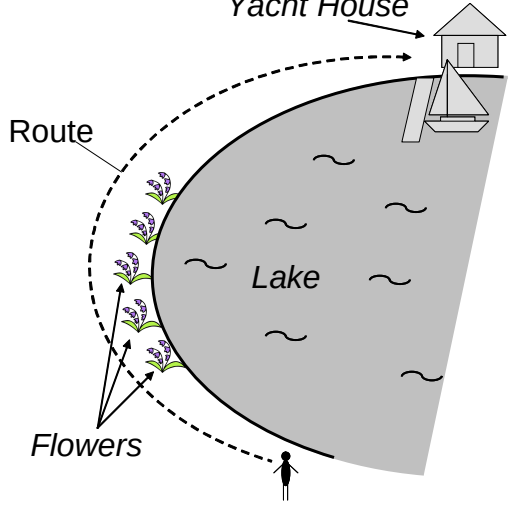



Figure 3: The spatial partition by the route in the route-centered perspective system

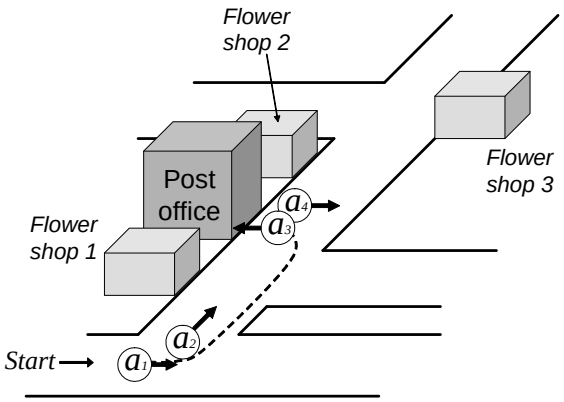



Figure 4: Action vectors

tioned according to the axes of the action vector. In case 2, if the agent regards the location of the crossing where he/she turned left as the action vector, the right region 'on the right' is determined by the right-left axis of the location of the crossing (Figure 2).

# Discussion

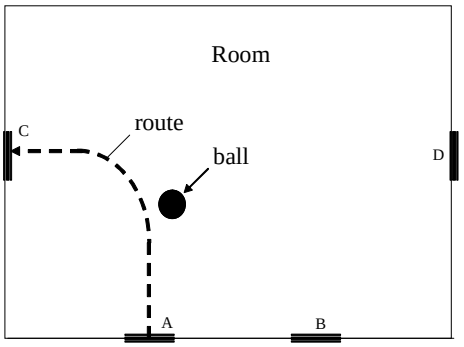
## Comparison with Herskovits's study

As for the discussion on the spatial partition, there is a well-known study presented by Herskovits [4]. Herskovits states that various kinds of paths (e.g., a pavement, a street, a river, etc.) and various kinds of areas (e.g., a field, a park, etc.) can be a reference object of an instruction, and the regions of a space is determined by the deictic perspective system. Here we discuss advantages of our method over Herskovits's study.

As for the case 1, if there is a pavement along the shore of the lake, the spatial configuration can also be explained by her perspective system. The pavement is regarded as the reference object of the instruction (i.e.,'right hand **of the pavement**') and the space is partitioned into the right and left regions along the pavement. In cases where there exists no pavement in a space, the spatial configurations remain to be explained in her theory. In the case 1, it is obvious that the route works as a reference object as explained by our route-centered perspective system.

The difference between her perspective system and ours can also be exemplified by the following example.

**(Case 3)** Consider the situation where the planner gives an instruction '*Enter the room through door $A$, pick up the ball on the right of the room and leave the room through door $C$'* (Figure 5).




*Enter the room through door $A$, pick up the ball on the right of the room and leave the room through door $C$.*

Figure 5: Case 3: A route followed by an agent picking up a ball in a room and an instruction

In her perspective system, the room is partitioned in the middle as shown in Figure 6 (a). With her perspective system, even if the agent looks around the right region of the room according to the axes of the room, he/she can not find the ball. The agent, however, will pick up the ball in the left region of the room. Such a behavior of the agent can be explained by both the route-centered and the position-centered perspective system as shown in Figure 6 (b) and (c) respectively.

## Comparison between the route/position-centered perspective systems

The difference between the route/position-centered perspective systems lies in the usage of routes; route-centered perspective uses a route an agent is going to follow (the future route), while position-centered one uses a route that have been followed by the agent (the past route).

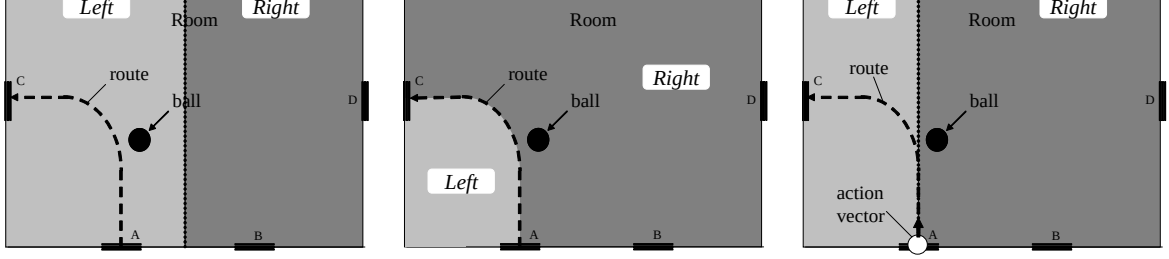



Figure 6: The spatial partition in Herskovits's perspective system (a), in the route-centered perspective system (b) and in the position-centered perspective system (c)

The route-centered perspective system can only be defined over the future route of the agent. This implies that the system can be applied only if the future route is determined by the given instruction. For instance, the route can be determined in the case 1, but it is not determined in the case 2. This is because the route in the case 2 is determined according to the interpretation of the instruction 'on the right' and the interpretation of the instruction cannot be determined until the route is determined.

On the other hand, the position-centered perspective system can only be defined over the past route of the agent. Remind that the action vectors, used as references in the perspective system, are the agent's former positions being set on the history of the route according to the instruction. This means that the position-centered perspective system cannot be defined over the positions on the route that the agent is about to follow.

## Conclusion

In this paper, we have proposed two perspective systems, the position-centered perspective system and the route-centered perspective system. Using the route-centered perspective system, we could describe that a route (an invisible line) could be regard as a reference object and partition a space. By partitioning the space along the route, we could clarify a region of the space, which was denoted by an ambiguous instruction with no reference such as 'On the right.' Using the position-centered perspective system, we showed explanation for a spatial configuration between objects and the agent's positions, which had been neglected to explain in the conventional perspective systems.

## References

[1] J. Araki, T. Ninomiya, T. Makino, and J. Tsujii. Action vectors for interpreting route descriptions. In *Proceedings of AAAI2002 Workshop on Spatial and Temporal Reasoning*, 2002.

[2] W. Burgard, A. Derr, D. Fox, and A. Cremers. Integrating global position estimation and position tracking for mobile robots: the dynamic markov localization approach. In *proceedings of International Conference on Intelligent Robots and Systems (IROS)*, 1998.

[3] K.P. Gapp. Basic meanings of spatial relations: Computation and evaluation in 3D space. In *Proceedings of AAAI-94*, pages 95–105, 1994.

[4] A. Herskovits. *Language and Spatial Cognition. An Interdisciplinary Study of the Prepositions in English.* Cambridge University Press, 1986.

[5] W. Levelt. *Speaking: From intention to articulation.* MIT Press, 1986.

[6] G. Retz-Schmidt. Various views on spatial prepositions. *AI Magazine*, 9(2), 1988.

[7] R. Simmons and S. Koenig. Probabilistic robot navigation in partially observable environments. In *Proceedings of the Fourteenth International Joint Conference on Artificial Intelligence (IJCAI'95)*, pages 1080–1087, 1995.

[8] B. Tversky and K. Hermenway. Objects, parts and categories. *Journal of Experimental Psychology: General*, 113(2):169–191, 1984.