Homing Navigation with Image Matching Approach

Jiwon Lee and DaeEun Kim

Biological Cybernetics, School of Electrical & Electronic Engineering
Yonsei University
Seoul, 120-749, Corea (South Korea)
(Tel : 82-2-2123-5879; Fax : 82-2-393-4010)
(E-mail: daeeun@yonsei.ac.kr)

Abstract: Many studies have tried to develop more accurate and highly sophisticate vision-based navigation algorithm. Simple and efficient navigation has been considered to save computation time and spatial memory. Bio-inspired navigation methods follow the navigation model of insects or animals, and it is believed that their mechanism use the image matching between the home snapshot image and the current snapshot image to determine the homing direction without any other information. This kind of simple navigation approach can be applied to robotic navigation. In this paper, we show the potential of the image matching approach for homing navigation

Keywords: visual navigation, image matching, bio-inspired robotics

I. INTRODUCTION

Extensive researches have been conducted on visual navigation. Many studies have tried to develop more accurate and highly sophisticate vision-based navigation algorithm. Yet simple and efficient algorithms are required for real application of navigation. Bio-inspired approaches to model animal behaviours are plausible ideas to find efficient navigation methods.

Many animals and insects are known to be able to return home by using the vision-based navigation system. Many animals including gerbils, hamsters, rats and pigeons use landmarks to find the location of their nest place.

The honeybee is a representative insect to use landmark navigation. Anderson argued that honeybees do not recognize the entire environment in great details, but use the configuration of surrounding objects roughly by dividing the visual environment into some sectors [1]. It means that honeybees show the visual environment as an overall configuration of landmarks. Anderson suggested a distribution model based on the concept of sectors to support the real experiments of honeybees.

According to the landmark navigation proposed by Cartwright and Collett [2], honeybees remember a snapshot near the nest and compare the current image with the home snapshot. Comparing the two images, the insect decides the homeward direction at any spot and ultimately approaches home. This image matching model becomes a basis of many insect navigation algorithms afterwards. Among them, we focus on the image matching algorithm established by Franz et al. [3].
They use the equidistance assumption that all landmarks are in the same distance and calculate the estimation of image displacements for every possible movement (direction). The image displacements produce a new snapshot image from the current image. The homing agent can choose the direction with the best matching score between the home snapshot and estimated snapshot. Franz et al. showed that the homing strategy is adequate for the robot navigation [3,4].

Standing on the basis of snapshot model, we have proposed a new method for robotic home navigation which is named *Sector-based image matching method* [5]. The method use the estimation process shown in Franz et al.'s approach with the equidistance assumption and the division of the image found in Anderson's model. The landmark position and the number of landmarks in a given sector can be considered as the image information and so pixel-by-pixel comparison in the Franz et al.'s approach is replaced by sector-by-sector comparison.

We compared the performance with Franz's image matching method. It has shown hat it is more efficient to return home in some regions than the image matching method in computer simulation. In this paper, we show experiments of a robotic navigation through the sector-based matching method, and discussed the performance and application for a robot.

II. METHOD

1. Pixel-based Image Matching

According to Franz et al.'s method, the visual information about surroundings is represented as a binary array of image. The binary 1 indicates the existence of landmark in a specific angle and binary 0 no landmark. We assume that the visual environment is taken as an omnidirectional camera information. A continuous part of binary values is a measure of the size of the landmark. Franz et al. suggested an estimation process for the next moving directions. For each directon, the information of surrounding landmarks can be converted to a new array of binary values – see Figure 1, if we know the location of landmarks. Here, they assume that all landmarks are in the same distance, which simplifies the calculation of the new image.

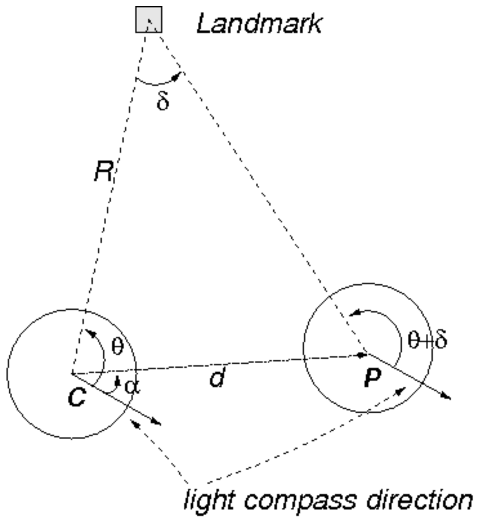


Figure 1. Visual displacements with a landmark (reprinted from [6])

The estimation image for each moving direction forms a virtual image from the current snapshot image. The image is compared with the snapshot image near the nest. The home snapshot is also recorded as a binary array of image. Here, the dot product between the two images to be compared produces the image matching level. The higher level means closer to the nest. If an agent chooses the moving direction with the best matching level, it has more chance to approach home. Surprisingly, this simple mechanism works well for the environment with surrounding landmarks.

2. Sector-based Image Matching

The concept of sector information is an index about how to recognize the visual environment. The whole image is divided into several sectors. For instance, if a robot recognizes the visual environment with five sectors, the range of each sector is 72 degrees of angular space in visual image. Each sector keeps the information of the landmarks which belong to the sector, for example, the number of landmarks and the landmark sizes. Visual environment is not recorded as pixel information, but as sector information.

The sector-based encoding uses two components, occupancy and landmark size difference. The occupancy is to check whether at least one landmark exists in each sector or does not. If a landmark is in a sector, the occupancy of the sector is set to 1 and otherwise, set to 0. The landmark size difference is how much the apparent landmark sizes are different at the nest and at an arbitrary point. It is equivalent to the distance difference of landmarks. The robot does not have to know the accurate size of individual landmarks as long as it knows how much a sector is filled with landmarks. If there are several landmarks in a sector, then the average size should be considered by checking how many landmarks are found and how much the landmarks fill the sector space.

Here, we also use the equidistance assumption that all landmarks have the same distances from each robot, the robot can easily calculate the distance from the landmark according to its size.

The matching score is calculated with the two factors, the occupancy and landmark size difference between the two snapshot images. One image is from the nest place and the other is from the current robot position.

Matching score = occupancy * (1-α*size difference)

where α is the scaling factor to normalize the size difference into [0,1]. The higher matching score indicates the more similar images.

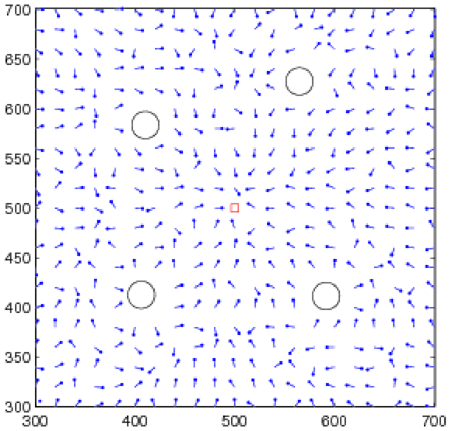
Considering both the occupancy and the size difference in the matching score allows the robot to recognize its relative position with respect to its surroundings.

III. EXPERIMENTS

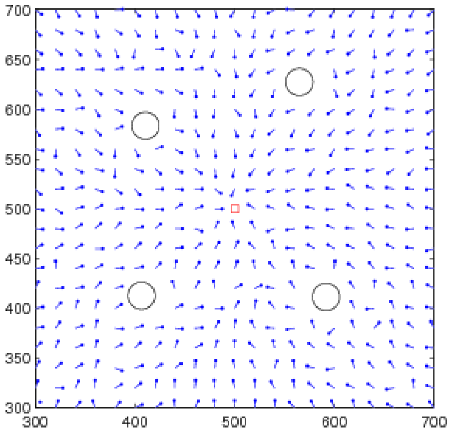
We tested the sector-based approach with simulation and robotic experiments. For a mobile robot, we used the Roomba cleaning robot and a laptop computer was mounted on the robot to control the motor actions. Also an omnidirectional camera (designed by Seunghun Baek in our lab) consisting of webcam and a metallic sphere was stacked on the top of the robot to take omnidirectional snapshot images.

We used red-colored cylindrical objects for landmarks. The omnidirectional image is converted into the panoramic image and the robotic system initially processes to find red-colored landmarks with a given color threshold, and the angular resolution is 1 degree and so the red-colored side is marked 1 in the binary array with a size of 360.

We pick up a set of test points in an arena and calculate the home vectors based on the sector-based approach. Without compass, the system needs to check all possible head directions as well as the moving directions. To reduce the time complexity, we use 72 head directions and 72 moving directions. The number of moving directions is related to the angular resolution of possible movements for the best matching score. We assume that all landmarks are in the same distance of 100 cm. The moving distance from the current position, the number of head directions, and the number of moving directions can vary. Two different numbers of head directions, 6 and 36 were tested. The moving distance is 10 cm, and 72 moving directions. Here, we used four sectors for the whole image. The result is shown in Figure 2. The number of head directions influences the vector map. More possible head directions have better performance for homing navigation.



(a)



(b)

Figure 2. Vector map with sector-based approach (dot direction: moving direction with the best matching score) (a) 6 head directions (b) 36 head directions (center point (500,500): home) (reprinted from [7])

We simulated the robot trajectory for any arbitrary position outside the landmarks and the robot can reach home successfully – see Figure 3. The pixel-based approach suggested by Franz et al. [3] shows that the agent can return home with high probability inside the landmarks, but it has difficulty in returning home inside the landmarks. In contrast, the sector-based approach shows effective homing navigation for any spot, if the rate of moving distance over the landmark distance is appropriately chosen.

With a similar environment, we tested the robotic navigation with sector-based approach. It shows similar performance to the simulation. Sometimes noise influences the homing direction, but generally the homing direction is very close to that in simulation results. Figure 4 shows the robot can return home with the sector-based approach regardless of different home positions.

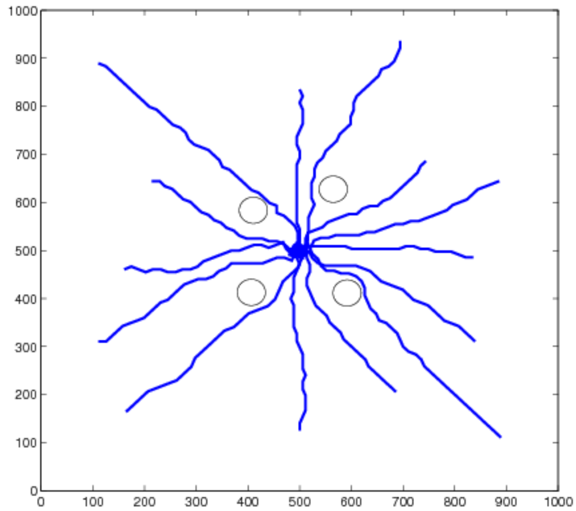
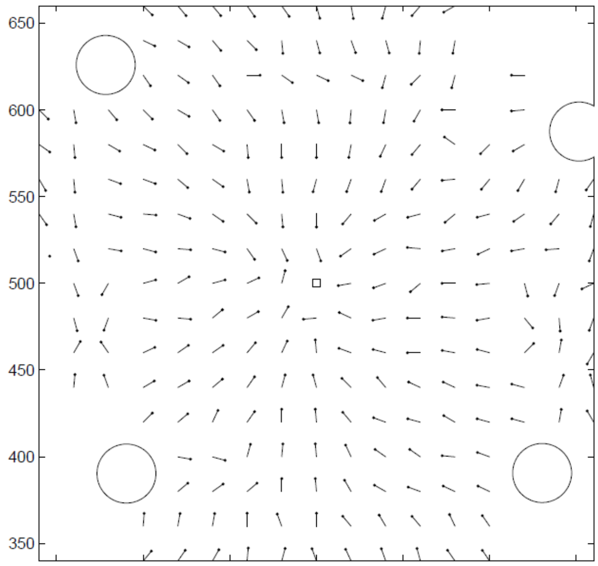


Figure 3. Trajectory map (reprinted from [8])

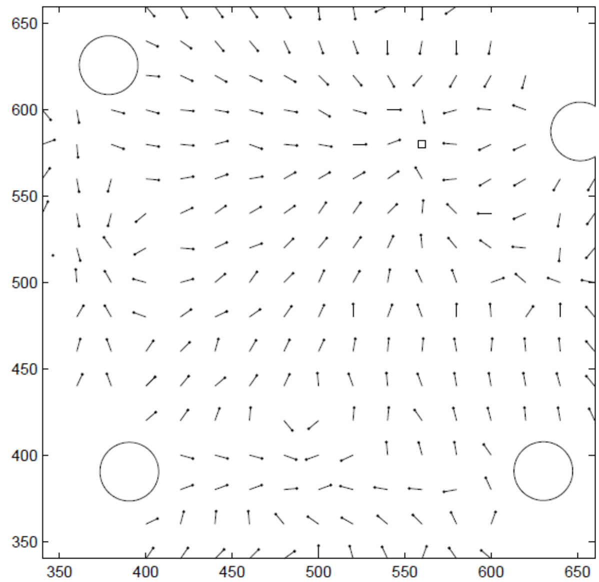
IV. DISCUSSION

The snapshot image is taken with an omnidirectional camera and the image covers landmarks for all the directions. The snapshot image is divided into several sectors. Each sector checks the landmark information inside the zone. We investigate several variations of sector-based approaches by overlapping the sector zones, increasing the number of sectors, or changing the size of sectors. Especially overlapping the sectors with an appropriate number of sectors may be more robust in noisy environments.

In this paper, we show that the sector-based image matching approach is a simple and efficient algorithm for a robot's navigation system based on visual landmarks. If the landmark navigation is combined with path integration mechanism, the agent can return home even for the area far from the nest. We can apply the path integration at far distance and use the image matching method at close distance. The sector-based algorithm reduces the time complexity by simple comparison of snapshot images, and also can efficiently find the way back home at a far distance or even under low resolutions of vision if the view of landmarks is available.



(a)



(b)

Figure 4. Vector map with robotic test over two different home positions (a) home (500,500) (b) home (560, 580) (reprinted from [8])

V. CONCLUSION

The image matching process records the snapshot image near the nest place, and compares the current snapshot image with the nest snapshot. Each snapshot image is divided into several sectors, and each sector encodes the landmark occupancy and landmark size. Then a pair of snapshot images are compared each other sector by sector. This suggested approach is more effective and efficient than the pixel-by-pixel image matching method. With the approach, a mobile robot can return home accurately with several landmarks, if it remembers the snapshot image near the nest.

VI. ACKNOWLEDGMENTS

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