Outdoor Navigation of a Mobile Robot Using Natural Landmarks

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Abstract

In this paper, we report how to navigate a mobile robot using natural landmarks such as trees and hedges on outdoor campus of university. At first, we propose an automatic natural landmark acquisition by Landmark Agent (LmA). Next, we propose an autonomous navigation using the acquired natural landmarks. Furthermore, we will discuss the difficulties of outdoor navigation using natural landmarks through some experiments about the landmark acquisition and autonomous navigation.

1 Introduction

Our objective of this research is to accomplish a long distance (approximately 1.5 km) outdoor navigation of a mobile robot on our university campus. Figure 1 is the photograph of the target environment. There is a paved road lined with trees, hedges and so on. The road can be assumed to be two dimensional. Figure 2 is the photograph of the YAMABICO NAVI robot, which is a self-contained and autonomous mobile robot for the outdoor experiments of this research.

Our navigation strategy is the playback navigation using Perceived Route Map (PRM) generated by automatic natural landmarks acquisition through route teaching[1]. After the human operator takes the robot to the goal once, the robot learns the task and the environment. Then the robot can navigate itself. In this paper, we focus on the natural landmarks acquisition and autonomous navigation using the natural landmarks.

2 What is a "natural" landmark

What is a natural landmark? A landmark is something, from which the robot can know the position. The landmark must permanently exist at the same location. A "natural" landmark means the landmark that is not prepared for the robot in advance. On two dimensional plane, the geometric location represents as a point or a line segment[2][3]. Trees, hedges and walls are used as natural landmarks on the target environment shown in Figure 1.

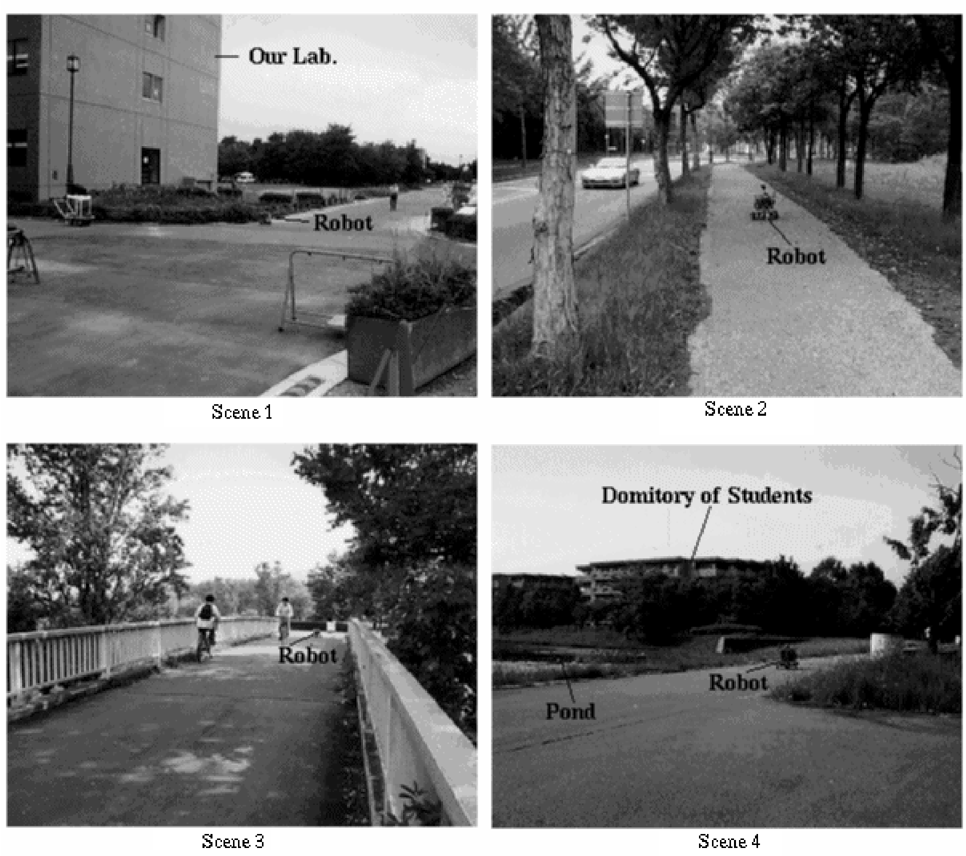

Figure 1: Photographs of the target environment

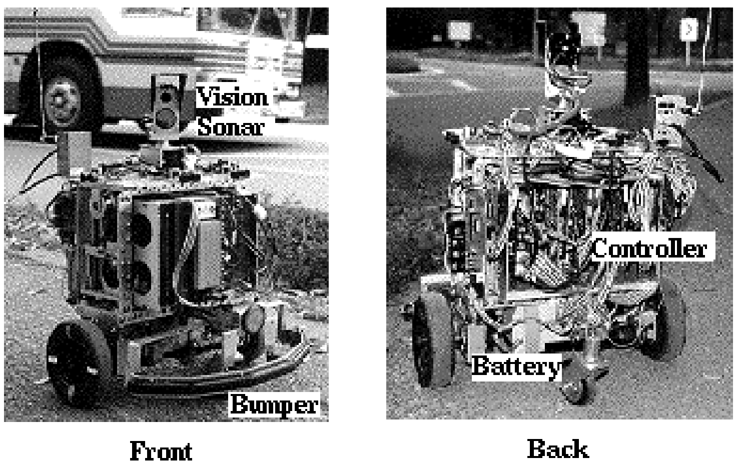

Figure 2: Photograph of the YAMABICO NAVI robot (The dimension (W x H x D) is about 450 x 600 x 500 mm^3. The weight is about 12 kg. The wheel diameter is about 150 mm. The tread is about 400 mm.)

3 Automatic acquisition of natural landmarks

To acquire natural landmarks automatically, the robot must extract good landmarks from sensor data by robot itself. It must be repeatedly observed at the same location with the same characteristics of landmarks even if the robot moves. So, we proposed a LmA (Landmark Agent)[1] with three states (SLEEP, WAKE UP and TRACK) shown in Figure 3. LmA is the agent to search each specified landmark. Each LmA has the model of the landmark to judge the expected one or not. By this model, the landmark candidate is repeatedly evaluated during tracking it.

For example, Tree LmA is the LmA to detect a tree as landmark. The parameters of "Tree" model are the average radius of the trunk of tree, two vertical edges generated in the image and no texture of the trunk in the image. Figure 4 shows the procedure of the tree tracking by Tree LmA. Of course, Tree LmA sometimes recognizes a different object as a tree. But, it is not so important that the detected tree landmark is a real tree or not. The important matter is that the detected landmark is repeatedly detected at the same location with the same characteristics by the algorithm of Tree LmA based on the tree model.

The Landmark Map is the set of the map by each LmA, which includes the sensing points of landmark, the location of landmarks and the characteristics of the landmark. PRM is the set of Landmark Map and Path Map which is stored the passing points of the robot during route teaching. All information in the PRM is generated from the information measured by the robot own sensors.

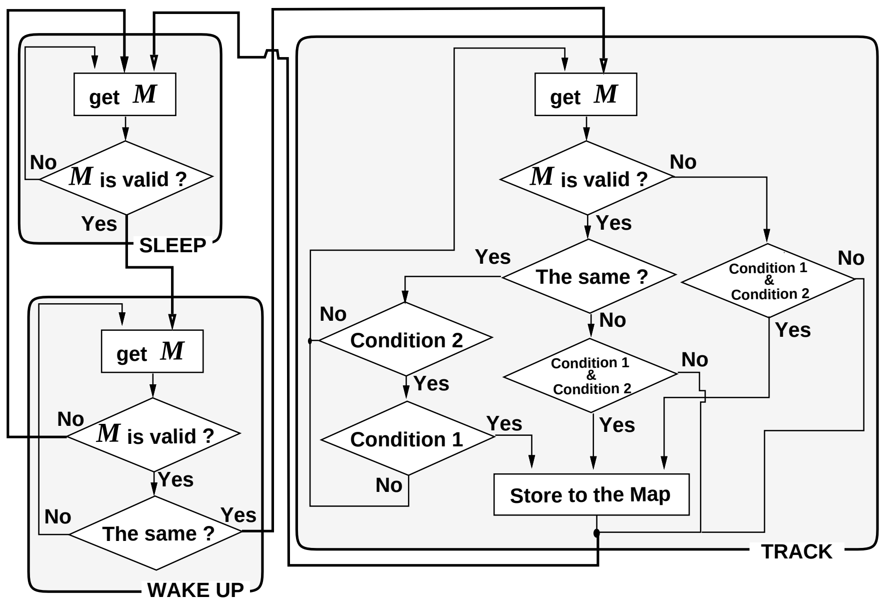

Figure 3: Formal procedure of landmark acquisition by LmA (M is measurement. Condition 1 : The times of TRACK are larger than the threshold. Condition 2 : The traveling distance during TRACK lager than the threshold.)

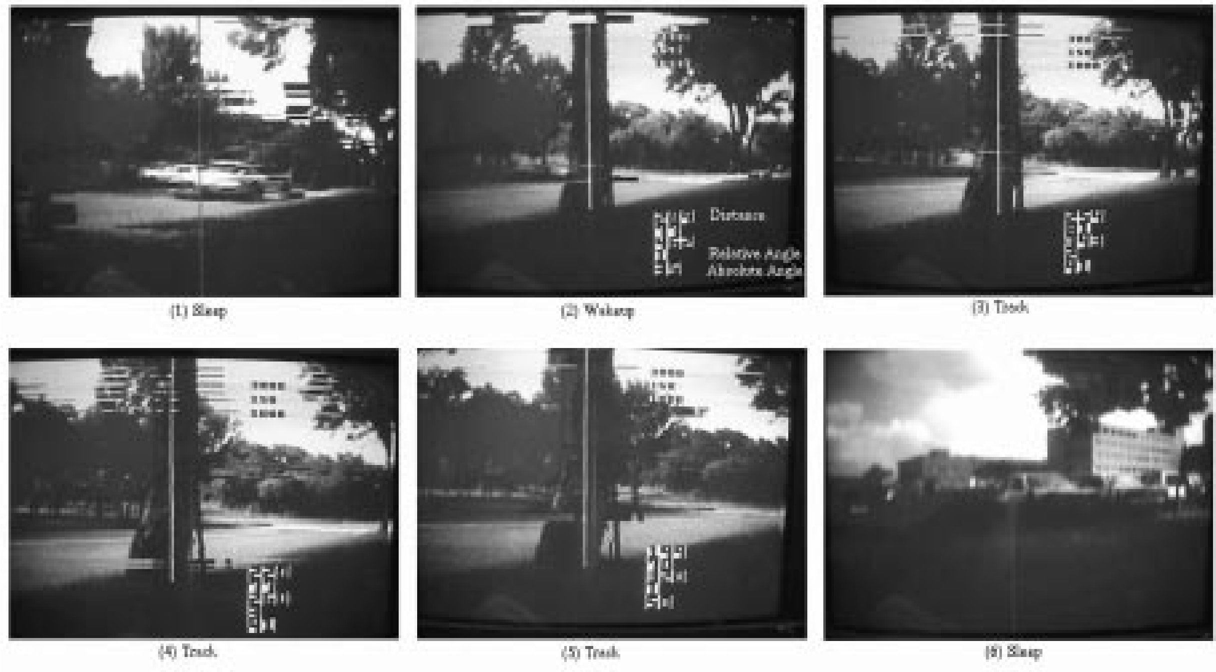

Figure 4: Tree tracking by Tree LmA when passing the tree landmark (Vertical white line indicates the detected tree position in the image)

4 Navigation using natural landmarks

Autonomous navigation is done by playback of PRM. The robot memorizes the path from the start to the goal in Path Map of PRM by route teaching in advance of autonomous navigation. If the robot can estimate the precise position, the robot can research to the goal by a feedback control of the estimated position. So, the research is focused on the position estimation. In our strategy of the position estimation, the position is continuously calculated by dead reckoning and occasionally corrected by landmark observation. Kalman filter is major technique for the position estimation of a mobile robot by sensor fusion[5][6]. In this method, both the position and the error covariances of the position are estimated by fusion of dead reckoning and landmark observation. The error covariances of the estimated position gives the weighted gain for sensor fusion to estimate reliable position, and the threshold value for judging the correspondence of landmark to avoid misunderstanding of the landmark. So, we also use the Kalman filter based position estimation [3].

The position correction by landmark observation is also executed by multiple LmA. Each LmA has an almost same simple algorithm shown in Figure 5. When the landmark is detected outside of the region of the estimated errors derived from the error covariances, the landmark is not used for the position correction to avoid misunderstanding of landmark. The above case is mainly caused by the masked landmarks or new objects added near the landmark. Therefore, it is very dangerous and causes a serious positioning error that the position is corrected by this doubtful information. When many LmA are installed on the robot and enough redundant landmarks are acquired in route teaching, the reliable position based navigation is realized.

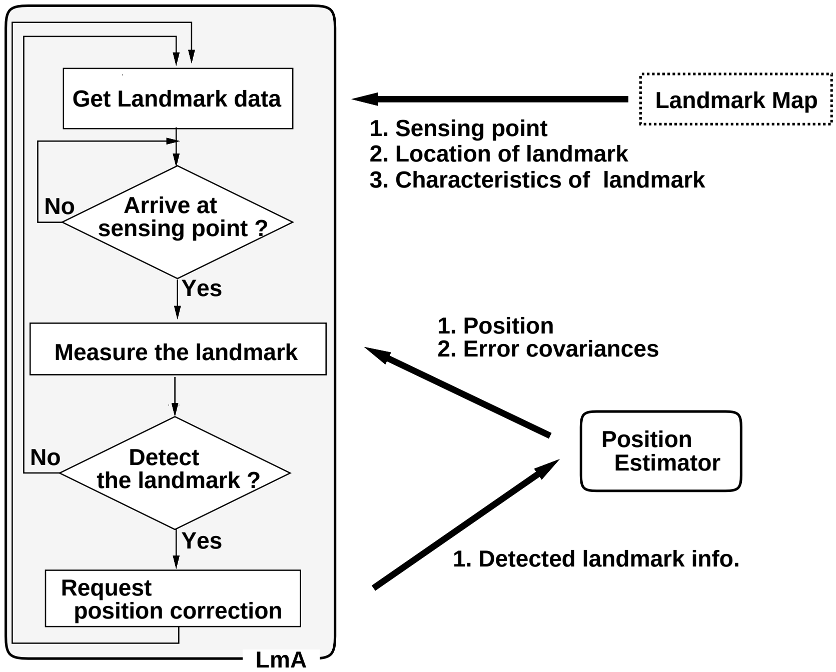

Figure 5: Use of the landmark map by LmA for autonomous navigation

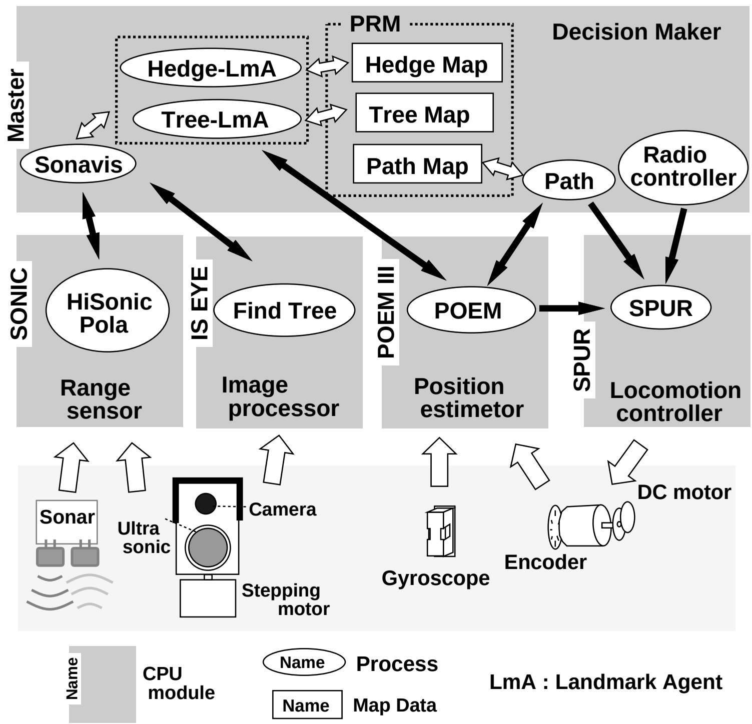

Figure 6: System configuration of the mobile robot YAMABICO NAVI.

5 Implementation

Figure 6 shows the system configuration of the YAMABICO NAVI. the YAMABICO NAVI has a dead reckoning system by fusion of odometry and gyro[7], SONAVIS [1] to detect landmarks, sonar to detect obstacles and two DC motors to drive the wheels.

The controller is distributed on multiple CPUs. The *Master* and the other functional modules have a connection like a star with Dual Ported Memory. The *MASTER* is a CPU module to control a total behavior of the robot. Information for decision making is gathered into the *MASTER*. The *MASTER* decides next motion from these information. Then, the *MASTER* gives the commands to the other functional modules. *YAMABICO NAVI* has functions of Locomotion control (SPUR[8]), Position estimation (POEM III[3]), Image processing (ISEYE) and Ultrasonic range sensing (SONIC).

The multi-agent system for navigation is implemented on the *MASTER*. *Hedge-LmA* is the Landmark Agent to detect hedges as landmarks when the distance measured at the same direction by ultrasonic sensor mounted on SONAVIS is almost same distance after traveling over 90 cm. *Tree-LmA* is one to detect trees as landmarks when the tree is detected at the almost same location by SONAVIS after traveling over 60 cm. *Sonavis Agent* is one to arbitrate *Hedge-* and *Tree-LmA*, since these two Landmark Agents use the same sensor property SONAVIS.

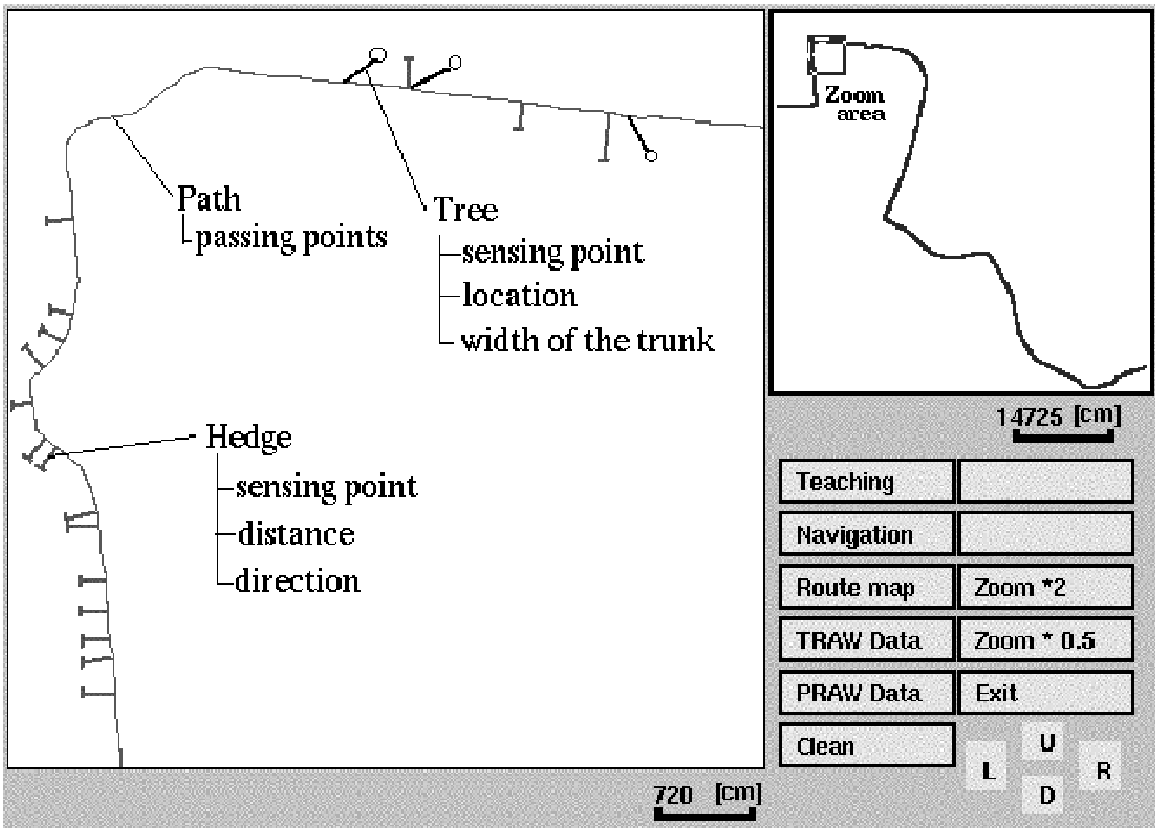

Figure 7: Experimental results about the automatic acquisition of natural landmarks

[1]SONAVIS is a landmark detection sensor with ultrasonic range sensor and vision mounted on a turn table.

6 Experiments

We made experiments about the acquisition of PRM by route teaching and navigation by playback of PRM in outdoor campus of our university.

The experimental result about acquisition of PRM is shown in Figure 7. The maximum speed of the robot was 30 cm/s. Total distance was about 1 km. Trees and hedges are detected as natural landmarks and the distance between each landmark is about 5m to 10m. We also confirmed that the robot could navigate itself about 100m by our strategy from some experiments of autonomous navigation. To get more longer distance autonomous navigation, we must develop more various LmA and the robot must get much more landmarks in route teaching. When the robot can acquire redundant amount of landmarks, the robot can select the landmark to use for position correction more strictly. However, we found it is very difficult to determine the thresholds about the times of TRACK, the traveling distance during TRACK and so on, to judge the reliable landmark or not. If the threshold is very strict, the robot can not get enough landmarks. But, the acquired landmarks are not reliable if the threshold is not strict.

7 Conclusions

To realize an outdoor navigation of a mobile robot in university campus, we proposed the natural landmark acquisition by LmA and the autonomous navigation using the acquired natural landmarks. Then, we implemented our proposed method on our mobile robot and made some experiments. For traveling more longer distance, the LmA is modified through many experiments and new LmA is incrementally added on the robot. In the future, we hope that our robot can robustly navigate itself about 1.5 km by using many refined LmA.

References

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