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Obtaining Environment Model Using Behavior-Based Robot System.

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Abstract

This paper presents a method for obtaining environment model by analyzing a record of behaviors. To analyze the record of behaviors, we use a statistical approach. The robot analyzes the record of behaviors, while wandering in an environment by behaviors which are an approaching to a feature and a leaving a feature in the environment. The robot detects characteristic behaviors from the record. This method does not refer strategy which depends on structure. Therefore, our method can apply a complex environment in which the robot cannot move along walls.

1 Introduction

In recent years, behavior-based robot systems have been extensively studied. The behavior-based system is decomposed into individual modules, each of which is responsible for one behavior to be performed by the entire system. Each behavior contains a complete path from sensing to action and is executed in a completely parallel manner. Even if one module fails, other behaviors can still produce meaningful actions for the robot. Therefore, the behavior-based system is more robust than a conventional AI-based system.

Practically, this system can execute low level tasks such as wandering in the environment and tracking objects. However, it is difficult that this system accomplishes high level tasks such as a path planning. We consider that the behavior-based robot system needs the environment model to efficiently accomplish the high level tasks, similarly as the conventional AI-based system.

The conventional method that obtains the environment model by behavior-based robot system divides the record of behaviors into same kinds of behaviors on a time axis.

In this method, the robot explores the environment and then represents it as a collection of behaviors, each of which corresponds to a local structure in the world [Mataric 92]. However, this method needs a strategy which depends on the structure such as moving along the walls. If the environment has a complicated structure as shown in Fig. 1, the mobile robot cannot apply this strategy to its environment. As a results, the mobile robot cannot obtain the environment model.

We propose the method for obtaining the environment model by analyzing the record of behaviors. The robot wanders in the environment and memorizes activated behaviors. To wander the environment, the robot utilizes the behaviors which are an approaching to the features and a leaving from the features in the environment. The used features, for example, are colors, intensity and so on. As a result, if two spaces have same features, two patterns of activated behaviors are similar.

Our method detects the pattern of the activated behaviors from the record of behaviors by using the statistical approach. The mobile robot divides the environment by using this pattern and obtains the environment model. Thus, we does not use the strategy which depends on the structure, to wander the environment. Therefore, the mobile robot can get the environment model of the complicated structure using our method.

2 Robot behaviors

The conventional method that obtains the environment model use the strategy which depends on the structure. Therefore, if the environment is complicated, the mobile robot cannot move and cannot get environment model.

On the other hand, in our method, the mobile

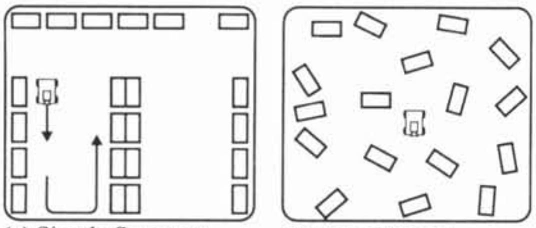

Fig. 1: Environment

robot wanders the environment by the two kinds of the behaviors. Therefore, we designed robot system as shown in Fig. 2.

2.1 Definition of the behavior

We defined the behavior as following;

- The behavior is composed for sensor information and action selection.
- The selected actions are "approaching to the feature" and "leaving from the feature".

Our system differs from the conventional system in the following;

- The behavior selects the action according to task.
- The action is either the approaching to the feature or the leaving the feature.

3 Segmentation of Environment

In our method, the mobile robot memorizes the activated behaviors and obtains the environment model by using the statistical approach.

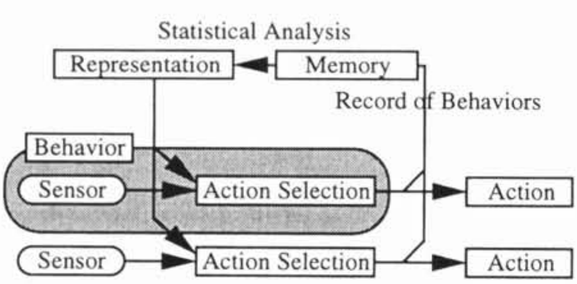

Fig. 2: Robot system

3.1 Record of behaviors

Our system uses the behavior which is activated by the feature in the environment. Therefore, the record of behaviors reflects the feature of the environment. As a result, analyzing the record of behaviors, we can analyze the environment in which the mobile robot wanders. Using this analytical results, the mobile robot can wander an area with same features and can segment the environment.

To analyze the record of behaviors, we use the statistical approach. The robot computes the following two statistical values.

- The mobile robot computes the number of the arrived features while wandering in the environment, and then computes the frequency distribution of these features by the following formula. The frequency distribution of the feature at time t is,

$$f_i(t) = \frac{n(f_i)}{n} \tag{1}$$

where n is the number of the all arrived features, and $n(f_i)$ is the time which the robot arrived the feature f_i. We call this $f_i(t)$ "frequency distribution function".

- To verify the convergence of the value of the frequency distribution function, the robot computes the variation of frequency distribution of each feature by the following formula. The variation of the frequency distribution of each feature is

$$v(f_i(k)) = \sum_{j=k-j_{max}}^{k} \frac{(f_i(j) - \overline{f_i})^2}{n(f_i)} \tag{2}$$

where j_{max} is the number of the sampling, and $\overline{f_i}$ is average of the frequency sequence of the feature f_i.

Using these values, the mobile robot selects the actions which are the approaching to the feature and the leaving from the feature.

3.2 Collecting features of local area.

First, to collect the features which characterizes the local area, the mobile robot approaches to the all features which is detected. To collect the features in the local area, the mobile robot limits the moving range. We call this moving range the maximum moving range. If the moving range of the mobile robot is over the maximum moving range, the mobile robot turns to a random direction and approaches to the other feature.

The mobile robot iterates these processes and collects the features in the local area.

3.3 Segmentation of local area

As described above, the mobile robot computes the statistical values while collecting the features in the local area. When the variation of frequency distribution of each feature is small than threshold, the mobile robot selects the actions according to the statistical values.

- The mobile robot leaves from the feature which is never detected and of which variation is larger than threshold.
- The mobile robot approaches the features of which variation is small than threshold.

4 Analysis of shape property of local environment.

Moreover, we evaluate the following parameters to analyze the shape of the environment.

1. The number of the step by the mobile robot arrives 100 features. (Parameter 1)
2. An error rate that the mobile robot cannot arrive at the feature. (Parameter 2)
3. The number of the step that the mobile robot cannot move. (Parameter 3)

Using these parameters, we detect the properties of the shape and complication of the environment. Parameter 1 and Parameter 2 show a size of the local area. Parameter 3 shows a complication of the local area.

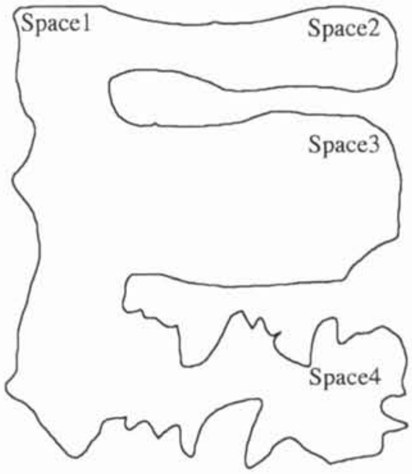

Fig. 3: Environment

5 Experimental Results

To verify the effectiveness of our system, we have tested our system in simulated environment. We arranged the features at a same interval. The environment is composed of fore local area with different features as shown in Fig. 3. Fig. 4 shows the example of variation of the convergence. The environment model which is obtained shows the Fig. 5. The number in this figure shows the ratio of the detected features. The shape properties of the each space show the Fig. 6. To compare the properties of each local area, each value is normalized.

6 Conclusion

We have proposed a method for obtaining environment model by analyzing the record of behaviors. To analyze the record of behaviors, we use statistical approach. This method does not use strategy which depends on structure. Therefore, our method can use complex environment such as the robot cannot move along wall.

We have verified the effectiveness of our method by simulations. As a result, we obtain the environment model with spatial relationship.

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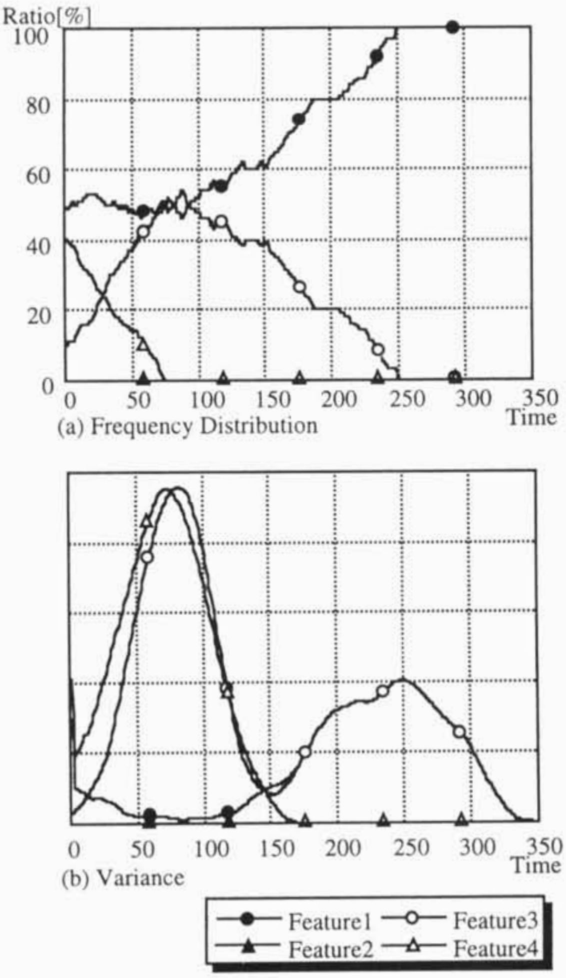

Fig. 4: Frequency Sequence and Varience

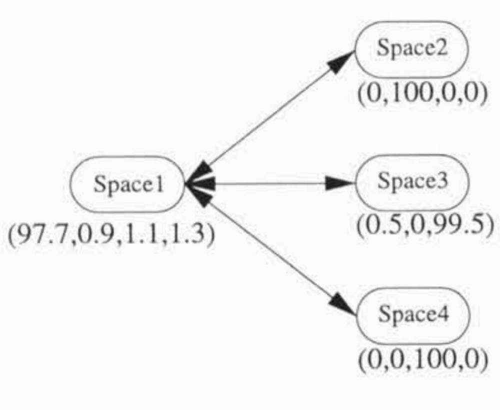

Fig. 5: Experimental Result

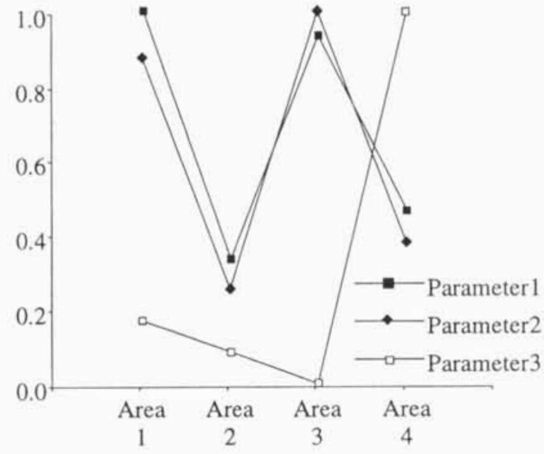

Fig. 6: Shape properties

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