Real-Time Self-Localization Using a Genetic Algorithm Based on Color Detection

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ABSTRACT

We developed a self-localization technique using an omnidirectional camera for an autonomous soccer-playing robot. Positional information is important for the robot's strategic behavior and cooperation. We developed a self-localization method, which uses white lines on the soccer field to generate a search space model, and a fitness function in a genetic algorithm (GA) to identify the robot's position on the pitch. We conducted an experiment to verify the accuracy of this method.

1. Introduction

RoboCup's main research goal is to study how multi-robot and multi-agent systems engage and cooperate with each other in dynamic situations, through the game of soccer [1]. On the RoboCup soccer field, robots use self-localization to estimate their own position, as well as those of the goals and other robots. They then use this information to decide on a strategy. The robot uses image information, environment information, and field information. In this paper, we describe a real-time self-localization method that applies a genetic algorithm (GA) for the RoboCup middle size league (MSL), which has the widest field size (12x18 m).

2. Hardware structure

We developed a robot with recent MSL technology: a high torque-driving module, a ball-handling module, an electrical kicking module using a solenoid, and a USB3.0 camera system.

The omnidirectional vision system (Fig. 1) of our robot consisted of a FLIR Flea3 camera, a Vstone varifocal lens, and a Vstone hyperboloidal mirror. An image captured by this vision system is shown in Fig. 2(a), and the image size and frame rate are 512 x 512 pixels and 30 fps, respectively.

3. Self-localization method

The robots use the white lines on the MSL field for self-localization. We developed a self-localization method that uses model-based matching to generate a search space based on the white line information from the soccer pitch. It then uses the fitness function to express the robot's correct position as the maximum value of the function. The self-localization method uses a GA [2] to optimize the fitness function.

3.1 Search model

Figure 2 shows the process of making the search model with our method. First, the camera takes a detection image of the white pitch lines. Second, we obtain the white detection image by converting the color space from RGB to HSV and YUV, as shown in Fig. 2(b). Third, we generate the field information by orthogonalizing the white line information, as shown in Fig. 2(c). Finally, we determine the search model by reducing the orthogonalized image, as shown in Fig. 2(d).

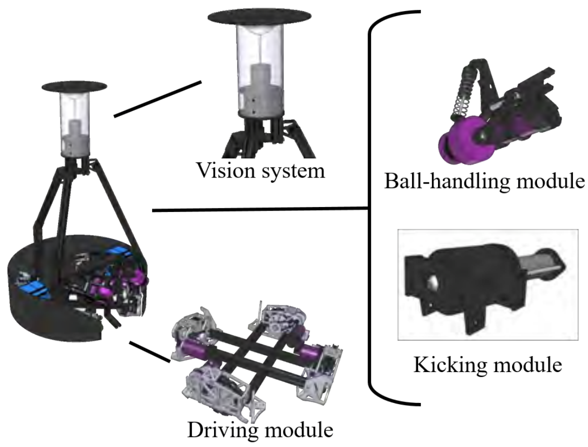


Fig. 1. Mechanical layout of our robot

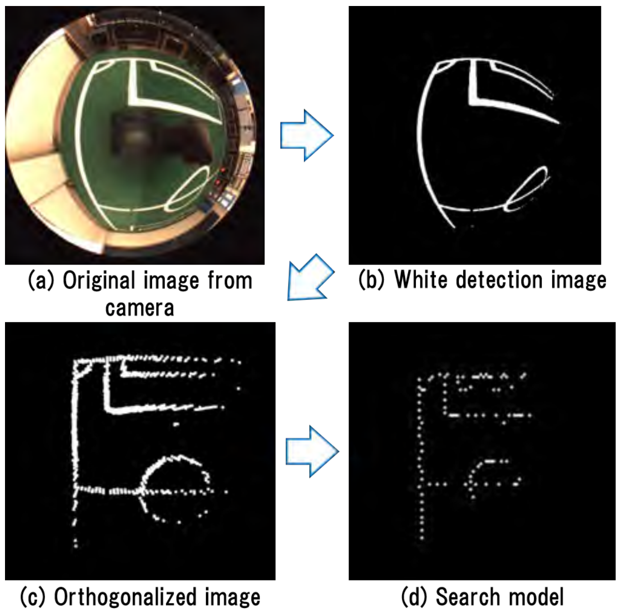


Fig. 2. Process of making search model

3.2 Model-based matching

Our self-localization method uses model-based matching to compare geometric information from the white lines on the MSL field and the search model to generate the search space. Let us denote the set of pixels that compose the search model shown in Fig. 3, as S_f. The position $\tilde{r} = (\tilde{x}, \tilde{y})$ and orientation $\tilde{\theta}$ of the search model in the image are represented as $\tilde{\varphi} = [\tilde{x}, \tilde{y}, \tilde{\theta}]^T$. Then the movement of S_f in the matching area is expressed as $S_f(\tilde{\varphi})$. Denoting the pixel value of the field image corresponding to the area of the moving model as $p(\tilde{r})$, $\tilde{r} \in S_f(\tilde{\varphi})$, the evaluation function $\mathrm{F}(\tilde{\varphi})$ of the moving model is given as follows.

$$\mathrm{F}(\tilde{\varphi}) = \sum_{\tilde{r} \in S_f(\tilde{\varphi})} p(\tilde{r})$$

The fitness function $\mathrm{F}(\tilde{\varphi})$ obtains the maximum value when the position of the search model corresponds to the same position as the robot on the MSL field. The problem of detecting the robot's position and orientation is converted to a search problem of $\tilde{\varphi}$ such that $\mathrm{F}(\tilde{\varphi})$ is maximized [3].

The calculation result of the whole matching area in Fig. 3 is shown in Fig. 4. The vertical axis represents the fitness value, and the horizontal axes represent the field plane. Here, we select only one maximum value depending on the value of an electric compass, because two maximum possibilities exist in the function value because of the revolution symmetry of the geometric shapes on the MSL field.

3.3 Genetic algorithm

In our self-localization method, we use a GA to find the maximum value of the fitness function $\mathrm{F}(\tilde{\varphi})$. GAs are a type of artificial intelligence and are parallel search-and-optimization processes that mimic natural selection and evolution. We use an elitist model to preserve the best individual in the population at every generation, genetic coding by gray code, roulette selection and one-point crossover. The parameters of the GA process are determined by previous experiments.

3.4 Verification

We performed an experiment to verify the effectiveness of the proposed self-localization method. Figure 5 shows the error between the correct position and the detected position in the quarter area of the MSL field at an interval of one meter. The severity of the error amount is indicated by the brightness of the gray scale. The average error was 12.7 cm, so the self-localization method is accurate enough for playing soccer.

4. Conclusion

In this paper, we described a self-localization method which generates a search space using model-based matching combined with white line information from the RoboCup MSL soccer field. It calculates the position of the robot by using a genetic algorithm to optimize the fitness function. We verified the effectiveness of the self-localization method and confirmed that it is accurate enough for playing soccer.

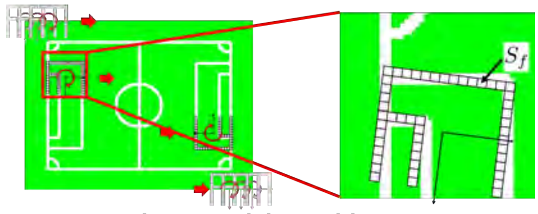


Fig. 3. Model matching

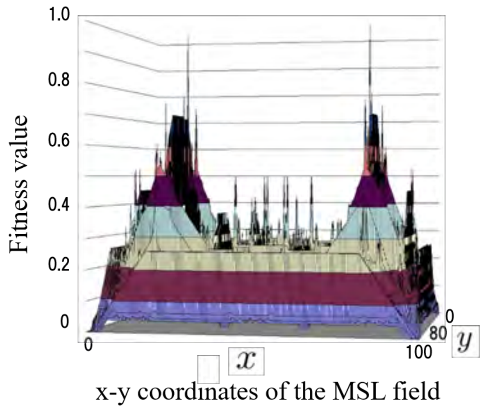
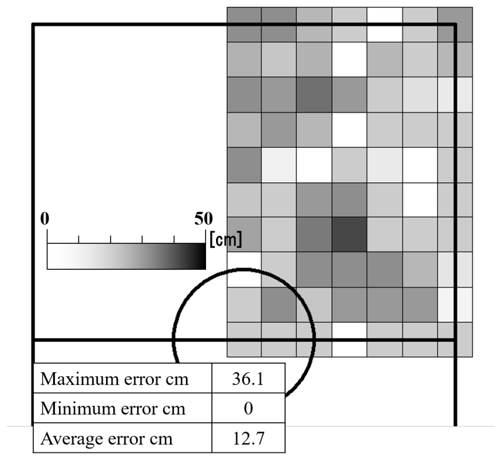


Fig. 4. Calculation result of the fitness function



Maximum error cm	36.1
Minimum error cm	0
Average error cm	12.7

Fig. 5. Self-localization error

5. References

[1] RoboCup Federation official website, https://www.robocup.org/

[2] D.E. Goldberg, "Genetic Algorithms in Search, Optimization and Machine Learning", Addison-Wesley, 1989.

[3] H. Suzuki, M. Minami, "Visual Servoing to Catch Fish Using Global/Local GA Search", IEEE/ASME Transactions on Mechatronics, Vol. 10, No. 3, pp. 352-357, June, 2005.