Real-Time Self Localization for Autonomous Robot of RoboCup MSL

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Abstract

This paper presents a self localization technique using an omni-directional camera for an autonomous soccer robot. The position information of the robot is important for strategic behavior and cooperative operation. Therefore, we have proposed the self localization method which generates the searching space based on a model based matching with white line information of soccer field, and which recognizes the robot position by optimizing the fitness function using Genetic Algorithm.

Keywords: Self-Localization, RoboCup Middle Size League, Soccer Robot, Genetic Algorithm

1. Introduction

The main focus of the RoboCup competitions is the game of football/soccer, where the research goals concern cooperative multi-robot and multi-agent systems in dynamic adversarial environments[1]. In the field of RoboCup, self-localization technique is important to estimate own position including goal and other robot positions and to decide strategy. Basically, we estimate the self-position with the image information, the environment information and the field information. In

Fig. 1. RoboCup MSL

this paper, we describe a real-time self localization method that applies a genetic algorithm (GA) for the RoboCup middle size league (MSL, Fig. 1), which has the widest field size (12x18 m). In Section 2 is hardware structure, which is overview of our past robot, driving module, ball handling module and kicking module. In section 3, vision systems, which are omni-directional camera module, self localization and ball recognition, are described.

2. Hardware structure

We have restructed the most part of hardware structure every year since our team was founded in 2008. We developed the robot based on recent MSL concepts that are high torque driving module, ball handling module, electrical kicking module using solenoid and USB3.0 camera system. We have called the platform as "Mugen"series[2], and "Mugen III(M-III)" shown in Fig. 3, which is improved and based on "Mugen" model, participated in RoboCup Japan Open 2017.

This high torque driving module equips 4-wheels and each wheel is Omni directional wheel. We use ball handling module for rotating a ball with natural direction. This kicking module can shoot a ball by solenoid.

3. Vision system

3.1. *Hardware of vision system*

The omni-directional vision system of our robot is consisted of the camera (FLIR, Flea3[3]), a varifocal lens (Vstone) and a hyperboloidal mirror (Vstone). We developed vision system shown in Fig. 2 for RoboCup MSL robot by combining with above elements. The image captured by this vision system is shown in Fig. 3(a), and the image size and frame rate are 512 × 512 [pixels] and 30 [fps] respectively.

3.2. *Self localization*

We employ a white line of MSL field for self localization. We have proposed the self localization method which generates the searching space based on a model based matching using white line information, and which recognizes the robot position by optimizing the fitness function which has the correct robot position as the maximum value of the function. And this proposed

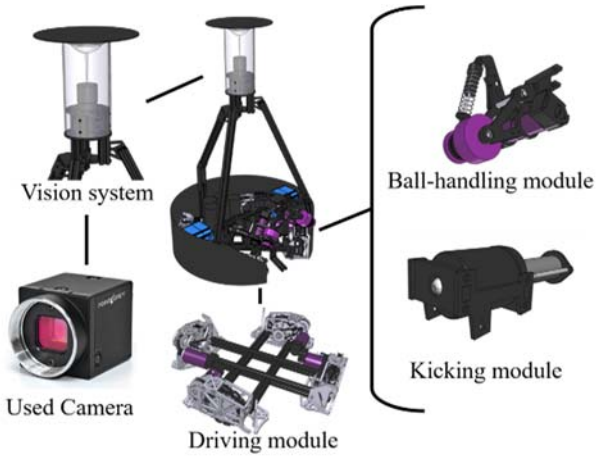

Fig. 2. "Mugen III" Mechanical layout

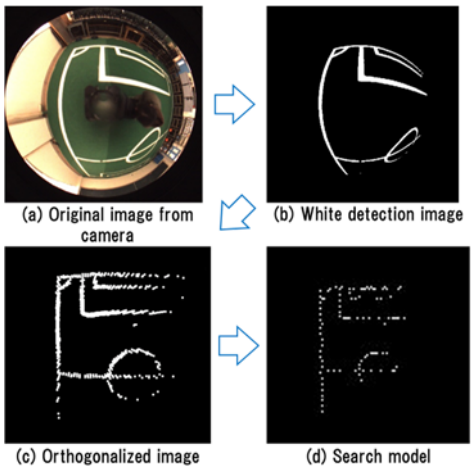

Fig. 3. Process of making search model

self localization method employs Genetic Algorithm (GA)[5] for optimization of the fitness function.

3.1.1. *Searching model*

Figure 3 shows the process of making the searching model of the proposed method. At first, we need the detection image of the white line for making the searching model based on the white line. We obtain the white detection image by employing the converting method of color space from RGB to HSV and to YUV like Fig. 3(b). And we generate the field information by

orthogonalizing the white line information like Fig. 3(c). Moreover, we determine the searching model by thinning down the field information based on white line like Fig. 3(d). Therefor we use thinned model as the self localization as model.

3.2.2. *Model-based matching*

The proposed self localization method generates the searching space by model based matching between geometric information of the white line in the MSL field and above-mentioned searching model. Let us denote the set of pixels, which compose of the searching model shown in Fig. 4, as $S_f(\tilde{\phi})$. The position $\tilde{r} = (\tilde{x}, \tilde{y})$ and orientation $\tilde{\theta}$ of searching model in the image is represented as $\tilde{\phi} = [\tilde{x}, \tilde{y}, \tilde{\theta}]^T$. Then S_f movement in the matching area is expressed as $S_f(\tilde{\phi})$. And, if the pixel value of field image corresponding to the area of the moving model is expressed as $p(\tilde{r}), \tilde{r} \in S_f(\tilde{\phi})$, then the evaluation function $F(\tilde{\phi})$ of the moving model is given as follows.

$$F(\tilde{\phi}) = \sum_{\tilde{r} \in S_f(\tilde{\phi})} p(\tilde{r}) \qquad (1)$$

The fitness function $F(\tilde{\phi})$ obtains the maximum value when the position of the searching model corresponds to the correct position that robot exist in the MSL field. Then, the problem of detection of robot position and orientation is converted to a searching problem of $\tilde{\phi}$ such that $F(\tilde{\phi})$ is maximized[6]. The calculation result of whole matching area shown in Fig. 4 shows Fig. 5. In this Fig. 5, the vertical axis represents the fitness value, and the horizontal axes represent the field plane. Here, we select only one depending on the value of an electric compass, because two maximum value exist in the function value caused by revolution symmetry of geometric characters of the MSL field.

3.2.3. *Genetic Algorithm*

In the proposed self localization method, we employ Genetic Algorithm (GA) for searching the maximum value of the fitness function $F(\tilde{\phi})$. A GA is an example of an artificial intelligence program and is well known as a parallel search and optimization process that mimics natural selection and evolution(Fig. 6). In the proposed method, an elitist model of a GA that preserves the best individual in the population at every generation is utilized and genetic coding using gray code, roulette selection and one-point crossover are employed. And, the

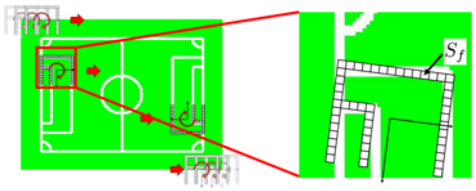

Fig. 4. Model matching

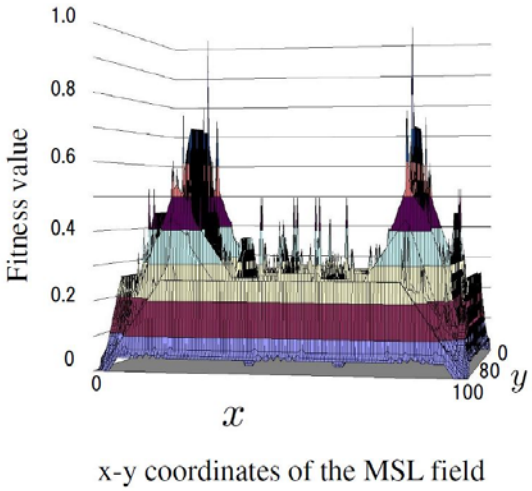

Fig. 5. Calculation result of the fitness function

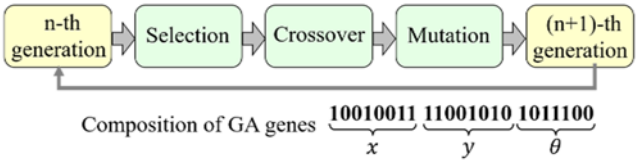

Fig. 6. GS's process

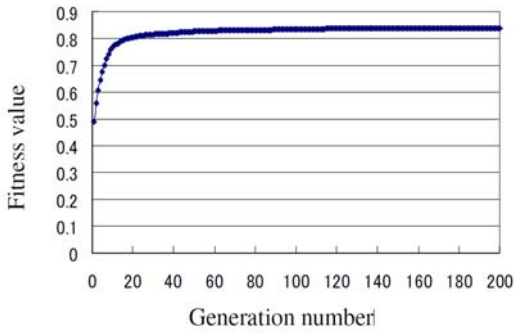

Fig. 7. Result of the convergence of GA

parameters of the GA process are determined by previous experiments. Figure 7 shows the result of the convergence of GA in case of self localization experiment using actual image that the robot captured at voluntary position. In this figure, the vertical axis represents fitness value of fitness function, and the horizontal axis represents the generation number of GA. The GA converged the maximum value, which means current position of robot in the MSL field, at about 60th generation in real time.

3.2.4. *Verification experiment*

We performed the self localization experiment to verify the effectiveness of the proposed method. Figure 8 shows the result of the verification experiment that checked the self localization error between correct position and detected position at the quarter area of the MSL field at interval of one meter. In this figure, each box represents the error as the brightness of gray scale. Average error of this experiment was 12.7[cm], and the accuracy of the self localization by the proposed method is enough to play soccer.

Moreover, we performed the experiment using five player shown in Fig. 9 on the assumption of MSL game. Laptop PC displays the position sended by each robot in real time, and the positions of five player described in the result image corresponded with the actual position of the robots.

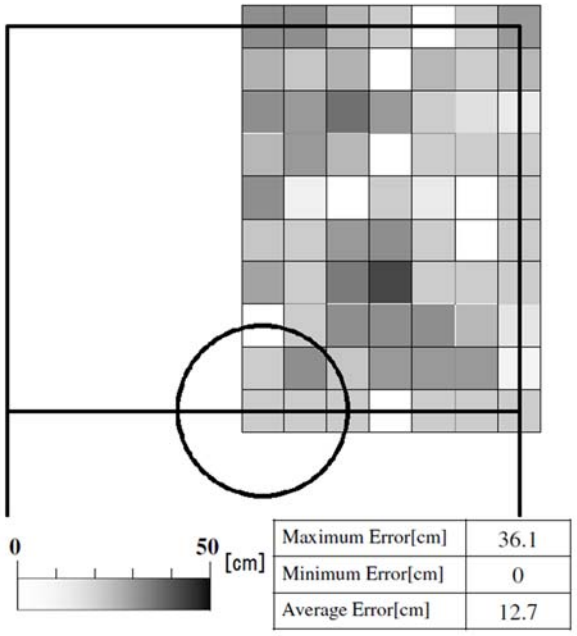

Fig. 8. Error of the self localization

Fig. 9. Verification experiment in the real world

4. Conclusion

In this paper, we have proposed the self localization method which generates the searching space based on a model based matching with white line information of RoboCup MSL soccer field, and which recognizes the robot position by optimizing the fitness function using Genetic Algorithm. Moreover, we verified the effectiveness of the proposed self localization method using GA. Furthermore, we confirmed that the accuracy of the self localization by the proposed method is enough to play soccer.

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