OMNIDIRECTIONAL ROBOT SYSTEM AND LOCALIZATION FOR FIRA ROBOSOT

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ABSTRACT

There are many ways to build a robot for FIRA Robosot. In the game, the robot should be able to dribble a ball skillfully and be able to move with perfect freedom. This paper describes the design process of building an omnidirectional robot platform and system for FIRA Robosot. The robot platform consists of Mecanum wheels, omni vision system with omni mirror and a camera. For robot localization, we proposes a robust localization algorithm to be used in the FIRA ROBOSOT playground.

1. INTRODUCTION

FIRA has become a popular competition over the world last few years. The first robot soccer game was Mirosot in which individual robot does not have sensing parts and only dependent on a global vision system. Mirosot robot system has been a well known testbed for Multi-robot systems. To implement a more realistic approach, robots were required to have fully independent autonomous system such as wireless communication, vision, sensing and control.

Recently, Robosot league was added to FIRA championship because of the demands of more sophisticated works upon robots. It is a game of robot soccer played between two teams of autonomous intelligent wheeled mobile robots on a field[1]. Robots are allowed to carry on board vision sensors rather than a globally supervised vision system. Wireless communication system is permitted between the robots and a remote host computer. Any human manipulation on the host computer is forbidden during the game except for a few rules. This possibly presents interesting challenge by requiring autonomous robot system in a team without human intervention. To achieve the goal, robots must have the capability to move swift with processing and drive mechanisms in addition to cooperation in a team and proficient vision capability[2][3][4].

In this respect, OmniKity series of robots developed at the RIT Lab were used for earlier Robosot competitions[5]. These robots had numerous attractive features such as an omnidirectionally differential drive and compact mechanical structure. However, these robots were too small to carry all the high-speed computer system, a complex dynamic system and a proficient vision system. In the previous work, to overcome demerits of Omnikity series, the design of a high speed holonomic omnidirectional robot was proposed with mecanum wheels and omnidirectional vision[1]. To play soccer autonomously, individual robot are required to indentify its position, which is called localization.

This paper improves the design, which was proposed in the previous paper, and integrates whole system with more well suited vision algorithm for Robosot. The omnidirectional robot system is equipped with mecMecanum wheels, omni vision system with omni mirror and a camera. Landmark based robust localization is also applied to an improved omnidirectional robot[8]. An integrated Robosot system is presented with well-qualified feature described above. This paper is organized as follows. Section 2 describes the platform design. The vision system for localization is discussed in Section 3 followed by the conclusion.

2. PLATFORM DESIGN

The overall design of the robot is shown in Figure 1. It has theee omni-wheels to perform omnidirectional movement and omni mirror is used for robot's omni vision system.

An on board PC is used for high level control such as path planning, communication, decision making. DSP controller is used for controlling three motors.

2.1. Mechanical Design

The robot has three omni-wheels which are oriented at 120 degrees from each other. The reason for using three wheels instead of four is that it makes much easier for three wheel robot to robustly contact with slightly irregular surface than four wheel robot. It requires extra mechanical structure for four wheel robot to robustly contact with the surface.

The concept of designing is to fix all motors, drive units and wheels as compact as possible to fit in a limited robot size.

It is made for the FIRA Robosot game, so it requires high performance, but it must also robustly handle dynamically changing environment. To obtain the high performance, 200W motors are used to drive the wheels so that the robot can move at a top speed of 3m/s. The platform has made with duralumin so that it is strong enough and it has a mass of 10kg. The base platform has a radius of 17cm with the wheels being located at a distance of 14cm from the center.

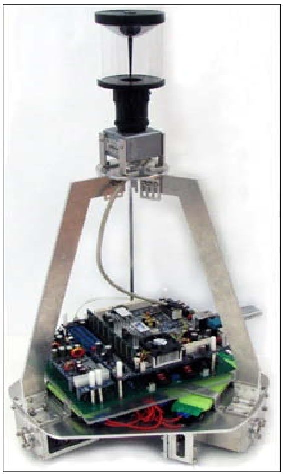

Figure 1 : Omnidirectional robot

2.2. Electronics Design

The electronics design contains four blocks; Processing board, complex devices, the control board and the robot platform. The processing board is connected with complex devices and the control board. It takes all outside data from complex devices and by using these data, it decides what to do next and send the action signal to the control board. The mini-ITX is used for the processing board.

The complex device block consists of camera and WLAN device. The resolution of the camera is 1600 by 1200 and omni mirror is attached on top of the camera. WLAN device is used for communication among agents.

The control board is used for getting action signal from the process board and making the robot move by controlling three motors. TMS320F2811 is used for the controller. It controls three motors by PWM signal and gets feedback from encoders of motors. For motor driver, LMD18200 is used.

The robot platform block represents motors, LCD and LED which are controlled by the control board.

3. VISION SYSTEM

3.1. Omnidirectional Vision System

The omnidirectional vision system provides the entire playground image thereby simulating a global vision system, similar to those employed in Mirosot. Using the image of the entire field, the robot localization can be performed.

The omnidirectional vision systems are classified into dioptric camera, catadloptric camera, and polydioptric camera. Dioptric camera and catedioptric camera are able to be embodied with low cost. However they have a shortcoming that an image from a camera suffers distortion. On the other hand, polydioptirc camera using many cameras can obtain a high resolution image without distortion. But it needs high cost and requires wide data bandwidth.

So the catedioptric camera is used because it can be embodied with low cost and has wider field of view(FOV) than dioptric camera. An example view from catedioptric camera is shown Figure 2.

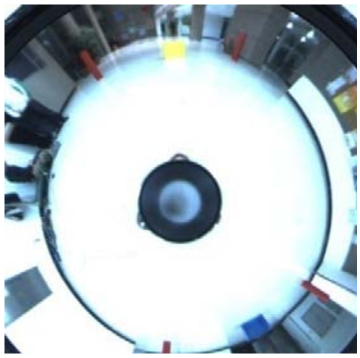

Figure 2 : View from catedioptric camera

3.2. Constant Intensity Color Space

In color image processing, changes in illumination, intensity of object, and shadow make color detection a difficult task. There are a number of researchers working towards minimizing these harmful effects. One well known approach is the use of a color space different from the RGB color space.

3.2.1. Intensity of RGB

Intensity of RGB color space is represented as follows:

$$intensity = (R+G+B)/3$$

where $(R,G,B) \in$ RGB color space.

3.2.2. Normalized RGB

Normalized RGB color space is represented as follows:

$$r = R/(R+G+B)$$

$$g = G/(R+G+B)$$

$$b = B/(R+G+B)$$

$$r+g+b=1$$

where $(R,G,B) \in$ RGB color space, $(r,g,b) \in$ normalized RGB color space.

3.2.3. Diff RGB

Diff RGB color space is represented as follows:

$$r' = R - G$$
$$g' = G - B$$
$$b' = B - R$$
$$r' + g' + b' = 0$$

where $(R, G, B) \in$ RGB color space, $(r', g', b') \in$ Diff RGB color space.

3.3. Localization using Omnidirectional Vision System

Localization function, by which a robot knows its position and orientation, is essential for robots to play soccer. Localization is generally categorized into local method using dead reckoning and global method using estimated data from environment[6]. Here, the robot system employed global localization using artificial landmarks in omnidirectional vision system.

Because omnidirectional vision system can easily obtain bearing information, localization uses a bearings-based algebraic method such as SVD instead of a geometric method. With this linear system the best solution can be found. Basically, however, bearings from a real world environment have inherent noise, which cause the solution in a linear system to be no longer optimal. [7]

Considering the imperfect information, u-MLESAC is utilized for the localization as parameter estimation based on MLESAC, in which the parameters of error model are estimated by expectation maximization with Monte Carlo Method[8]. u-MLESAC is a parametric approach with the combination of Gaussian distribution and Uniform distribution to represent inliers and outliers.

A. Probabilistic Error Model

The probability distribution of error is modeled as follows:

$$\mathrm{p}(e|M) = \sum_{j=\{0,1\}} \mathrm{P}(z=j|M)\mathrm{p}(e|z=j,M)$$

where p(e|z = j,M) is an error probability distribution of an inlier (j = 1) or outlier (j = 0), and P(z = j|M) is a prior probability to be an inlier or outlier. A posterior probability is derived as

$$\mathrm{P}(z=j|e,M) = \frac{\mathrm{P}(z=j|M)\mathrm{p}(e|z=j,M)}{\sum_{k=\{0,1\}}\mathrm{P}(z=k|M)\mathrm{p}(e|z=k,M)}$$

Prior probabilities are noted as P(z =1|M) = and P(z = 0|M) = 1 - γ . Torr and Zisserman [9] introduced an error model as follows :

$$\mathrm{p}(e|M) = \gamma\frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{e^2}{2\sigma^2}\right) + (1-\gamma)\frac{1}{\nu}$$

where ν is the size of error space. It assumes probability distribution of inlier error as unbiased Gaussian distribution and outlier error as uniform distribution. Besides, its posterior probabilities become

$$\mathrm{P}(z=0|e,M) = 1 - \mathrm{P}(z=1|e,M)$$

$$\mathrm{P}(z=1|e,M) = \frac{\gamma\frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{e^2}{2\sigma^2}\right)}{\gamma\frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{e^2}{2\sigma^2}\right) + (1-\gamma)\frac{1}{\nu}}.$$

B. Error Distribution Estimation

Since Torr and Zisserman's model is a parametric model, it is necessary to estimate the two variables for obtaining error probability density $\mathrm{p}(e=e_i|M)$. Choi[10] uses EM with multiple initial values. Since it is unbounded, but σ^2 is bounded from 0 to 1, this paper estimates σ^2 through EM with multiple values of γ . The variable σ^2 is updated as

Γ and $\sum$, which maximize the expectation, are as follows:

$$\sigma^2 = \frac{\sum_{i=1}^n w_i e_i^2}{\sum_{i=1}^n w_i}$$

where w_i is posterior probability P(z_i = 1|e_i,M) (12) which maximizes expectation of likelihood with respect to unknown data classes.

C. Model Parameter Evaluation

According to Bayesian approach, when m is a random variable in a parameter space, probability p(m = M|e_1, e_2, …,e_n), shortly p(M | $\mathcal{E}$), represents how parameters M are probable with respect to given errors $\mathcal{E}$. However, the distribution of the random variable m is unknown, so it is popular to use likelihood p($\mathcal{E}$|M) under assumption that P(M)/P($\mathcal{E}$) is constant. The likelihood is represented as follows:

$$\mathrm{p}(\mathcal{E}|M) = \prod_{i=1}^n \mathrm{p}(e_i|M)$$

It is common to use log likelihood for computationalefficiency, so this paper uses negative log likelihood as follows:

$$\mathrm{NLL}(M) = -\ln\prod_{i=1}^n \mathrm{p}(e_i|M) = \sum_{i=1}^n\left(-\ln\mathrm{p}(e_i|M)\right)$$

which evaluates parameter M with respect to errors. Now, the problem to maximize the likelihood is formulated as

$$\hat{M} = \arg\min_M \mathrm{NLL}(M) = \arg\min_M \sum_{i=1}^n\left(-\ln\mathrm{p}(e_i|M)\right)$$

Finally, to find optimal termination time for maximizing the accuracy of the estimation, the relative efficiency is adopted. The overall process of the estimator is described in Figure 3.

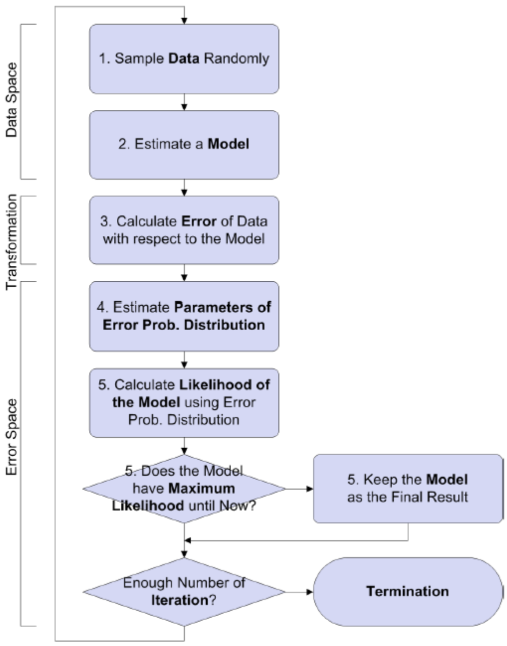

Figure 3 : The overall process of the estimator

4. CONCLUSION

The paper discussed the overall design process of the omnidirectional robot for FIRA Robosot. The integrated system architecture and design of the electronics, drive systems and the mechanical design were presented. The vision algorithm was detailed and the basic localization scenario was also briefed upon. We hope that the extensive design process results in a highly effective autonomous robot for FIRA Robosot.

5. REFERENCES

[1] N.S. Kuppuswamy, SH Cho, D. Stonier, SL Choi, J.-H Kim, “Design of an Omnidirectional Robot for FIRA ROBOSOT,” *FIRA*, 2007

[2] Jung, M.-J., Jang, J.-S., Kim, J.-H., “Development of Robosot Category Soccer Robots”, *Journal of Harbin Institute of Technology*, Vol 8. (3) pp.300-302, 2001.

[3] Kim, J.-H., Vadakkepat, P., “Multi-Agent Systems : A Survey from the Robot-soccer Perspective,” *International Journal of Intelligent Automation and Soft Computing*, Vol. 6:(1) pp.3-17, 2000.

[4] J.-H. Kim, Kim, K.-C., Kim, D.-H., Kim, Y.-J.,Vadakkepat, P., “Path Planning and Role Selectrion Mechanism for Soccer Robots,” *Proceedings of the 1998 IEEE International Conference on Robotics and Automation*, Leuven, Belgium, pp. 3216-3221, 1998.

[5] Jung, M., “Development of Omnidirectional Wheeled Mobile Robots Using Structural Properties,” PhD Thesis, *Department of Electricial Engineering and Computer Science*, KAIST, 2002.

[6] S. Choi, JS Sun, JH Kim, “Multi-agent Soccer Robot Technology, its application and research direction,” *Korea Robot Society Paper*, vol. 4, no. 4, Oct 2007.

[7] I. Shimshoni, “On mobile robot localization from landmark bearings,” *IEEE Transactions on Robotics and Automation*, vol. 18, no. 6, pp. 971 – 976, December 2002.

[8] S. Choi, “Robust Parameter Estimators for Dynamic Data Distribution and Its Application to Landmark-based Localization,” *Master thesis*, KAIST, 2008.

[9] P. Torr and A. Zisserman, “MLESAC: A new robust estimator with application to estimating image geometry,” *Computer Vision and Image Understanding*, vol. 78, pp. 138–156, 2000.

[10] SL Choi, J.-H Kim , “Robust Model Parameter Estimator for Dynamic Data Distribution and Its Application to Landmark-based Localization,” *in Proceedings of the 2008 IEEE Systems, Men, and Cybernetics*, 2008. (Accepted)