Ball Dribbling Control for RoboCup Soccer Robot

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Abstract

RoboCup is a platform designed to promote the research related to Artificial Intelligence (AI) and robotics. We also organize a RoboCup soccer team “Hibikino-Musashi” and working on co-operated behavior control system using multiple autonomous mobile robots. In order to realize co-operated behavior in the soccer game, the ball handling system is one of the important issues for dribbling and passing the ball to teammate robots. In this paper, a control method of the ball rotation using two active wheels, which are attached in front of the soccer robot and designed to have friction on the upper side of the ball, is proposed. The forward and inverse kinematics between the ball-motion and two active wheels are derived, and the ball handling mechanism is developed and evaluated based on the results of simulations and experiments.

Keywords: RoboCup; ball-wheel kinematics, ball handling mechanism

1. Introduction

The robot competition RoboCup is proposed to be a landmark project whose target is to realize the robot soccer team to defeat the human World Cup champion team until 2050. The project is expected to encourage

researchers to develop and promote Artificial Intelligence and robotics from different aspects [1]. The soccer robots should be autonomous and make a goal in the dynamic environment where many robots move around intricately intertwined with other friend and opponent robots. On developing the co-operated

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behaviors using soccer robots, the invention of new technologies is expected because not only the technical issues of robot development but also human-robot interactions should be considered such as safety regulations not to damage human and robot themselves, reading the situations, ambiguous determinations and so on. The robot technology will be utilized in service markets and human-robot interactive tasks in the future.

We also organize a RoboCup soccer team “Hibikino-Musashi” to join RoboCup Soccer Middle Sized League (MSL) and working on co-operated behavior control system using multiple autonomous mobile robots. To promote intelligence of robots, MSL rules are annually reviewed and updated. In recent years, top teams’ robots show collaborated behaviors as a team and different ball passing methods for various situations are developed to achieve high score. In order to realize co-operated behavior in the soccer game, the ball handling system is one of the important issues for dribbling and pass the ball to teammate robots. The quick motion of robots with high ball retention capability has the big influence on planning the action of the robot.

The new soccer robot of “Hibikino-Musashi” is shown in Fig. 1. The robot has omni-directional mobility and an omni-vision camera system on the top, and is controlled by a mounted laptop computer. Comparing with our previous robot [2], the new one can move 1.5 times faster and has the ball handling mechanism in front.

In this paper, a control method of the ball using two active wheels, which are mounted in front of the soccer robot and designed to have friction on the upper side of ball, is proposed. The forward and inverse kinematics between the ball-motion and two active wheels is derived, and the ball handling mechanism is developed and evaluated based on the results of simulations and experiments.

2. Development of Ball Handling Mechanism

Several different ball handling mechanisms for soccer robot have been reported in literature [3], which are mainly classified into two types, one is to control the ball by using two active wheels mounted in the front of the robot and another is by using arms [4]. With the selection of soccer robots going on, the ball handling mechanism by two active wheels has become the mainstream. The advantage of the ball handling mechanism using active wheels is the capability of keeping the ball even in the lateral- and reverse-motion. On the other hand, the disadvantages of the mechanism are the complexity in design and necessity of ball motion control algorithm suitable to the robot motion. The ball should rotate smoothly with respect to the traveling direction of the robot to satisfy the RoboCup regulation and realize smooth robot motion. Moreover, the ball handling mechanism is restricted to cover one-third of the ball [5]. The RoboCup team TechUnited developed the mechanism using two normal wheels and a solenoid kicker which can keep the ball and select loop-pass or header-pass [6]-[8]. CAMBADA team developed using two omni-wheels and shows the similar function [9]. However, the forward and inverse kinematics between ball motion and wheels are not well defined and the ball motion is controlled by heuristic methods. We introduce the mathematical model regarding ball motion and active wheels.

The overview of mathematical design of the ball handling mechanism is shown in Fig. 2, and the schematic design is in Fig. 3. In the mechanism, active wheels are attached to the lever tips to rotate the ball. The two levers move upward passively when the active wheels rotate to bring the ball toward its body, and the springs and dampers are connected between the body and the levers to absorb the collision impact of the ball. The small omni-wheels in the bottom are passive rollers to prevent the ball from contacting to the body. If the robot detects the approaching of the ball, the active wheels on the levers start to rotate to bring the ball inside the robot, the friction between the ball and wheels generated by the spring force get the ball inside the robot.

To recognize the ball situation, the lever shifting angle $\alpha_L$, which is the angle from the initial position $\alpha_{SP}$ to the maximum angle $\alpha_{HP}$, is measured by the potentiometer. Then, $\alpha_L$ equals to $\alpha_{HP}$ (Fig.4), the active wheel control starts to synchronize with robot’s movements. The ball handling mechanism is designed to hold the ball by four wheels during dribbling.

![Fig. 1. Soccer robot of “Hibikino-Musashi”](image)

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3. Kinematics and Experimental Setup

The forward and inverse kinematics between ball motion and active wheels are represented as shown in eq. 1, [10].

\[ \dot{\omega}_W = \left( \frac{\left\| \dot{\omega}_B \times \vec{P} \right\|}{r_W} \right) \cdot \vec{r}_W \]  \hspace{1cm} (1)

Wheel angular velocity vector \( \dot{\omega}_W \) can be expressed by velocity vector at contact point and wheel radius \( r_W \). Velocity vector at contact point can be expressed by ball angular velocity vector \( \dot{\omega}_B \) and position vector \( \vec{P} \) from the ball center to contact point.

To evaluate the kinematics, following experiments are performed to obtain the state variables of ball motion and active wheels. In the experiments, the distance between the wheel and the ball is required to be constant, so that an experimental setup is developed as shown in Fig. 5 and Fig. 6.

The setup is designed to be able to change its wheels around the ball in arbitrary position and angle. Totally, six encoders are attached to the robot as an internal sensor to measure two motions, ball motion and wheels. The four encoders are to determine velocity and orientation of the experimental setup and installed on each omni wheel. The two encoders are attached directly to the active wheel motors.

4. Experimental Results

The kinematics between ball motion and wheel is evaluated by translational motions in surge, sway and their combination (see Fig. 7-9). The solid and dot lines mean the velocity in x-direction and y-direction, respectively. Black line means the forward kinematics.
obtained from active wheels’ data, and blue are from experimental setup motion.

In the evaluation of surge motion (y-direction in the robot coordinate), the ball is controlled to go backward 270 (deg.) with the velocity of 1.0 m/s. The comparison of the velocities from setup motion and kinematics calculated by active wheel rotation is shown in Fig. 7. The result shows that the experimental setup motion is well controlled to be 1.0 m/s, and velocities from the setup and calculation of kinematics become almost same values.

In the sway motion (see Fig. 8), the velocity of x-direction is controlled to be 1.0 m/s. The experimental data of setup show also good consistent with kinematics calculation. In the experiment of Fig.9, the ball is controlled to go in 225 degree and the velocities in x- and y-direction are equal. As the result, the ball moves in about 240 degree, however, the ball motion data and kinematics calculation show good consistent.

5. Conclusion

In this paper, the forward and inverse kinematics between the ball-motion and two active wheels are evaluated by surge and sway motions using developed experimental setup. The results show that the ball motion data and kinematics calculation show good consistent. The ball handling mechanism has enough possibility to realize dribbling behavior of the soccer robots.

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