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Spinning Control of Basketball with Robot Fingers

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Abstract: In this paper, we consider dexterous manipulation by robot hand through spinning control of basketba ll. We investigate a spinning basketball, and propose that control process for keep up spinning basketball on f ingertip. This problem is to control manipulating a dynamic object under equilibrium grasp. We analyze the m otion characteristic of a ball that spinning at high speed and its on a fingertip, and propose the control metho d to prevent the ball from dropping by the feedback control. And, we verified the effectiveness of this metho d by the simulation.

Keywords: Amusement robot, Ball-spinning trick, Dexterous manipulation, Equilibrium grasp

I. Introduction

A robot hand has dexterous fingers is important element for intelligence humanoid robot. So, many robotics researcher studies robot hands possible humanlike dexterous work. However, it is not easy to achieve it by robot hand because dexterity of human hand. When manipulating the object, which is constrained from the hand in the form that is called force-closure and form-closure[1] in the many researches manipulation that using robot hand. At this time, the object is constrained by fingers of an enough number, and grasped by an appropriate finger force. When the manipulation object is dynamic, it is preferable to reduce the contact point with the object.

In the researches about dexterous manipulation that using robot finger and hand, there are Pen spinning by Ishihara and others[2], Dish spinning by Kajiwara and others[3], and Rolling based manipulation by Harada and others[4]. In [2], Ishihara and others have achieved a dynamic pen spinning using multifingered hand by feedback system. In [3], Kajiwara and others have achieved a dish spinning by robot with the open-loop control. And in [4], Harada and others achieved the manipulation of a object on the robot hand by the trajectory planning of the manipulation object. This like, the research on a dexterous manipulation with the robot hand is done by various approaches. However, there is no research, manipulating a dynamic object by the feedback system under equilibrium grasp yet. And so, we chose spinning control of basketball as a dynamic model that achieved such a control, and achievement by the robot was tried.

This is like basketball player plays spinning a ball on own fingertip. But, we were not able to find the document that had been described how to spin a basketball on fingertip. Then, first of all, we analyze the mechanism of ball spinning, and show the condition to manipulate the ball with stability. And, we propose control techniques to achieve spinning a ball by robot hand, and show the effectiveness by the simulation.

II. Spinning Ball Dynamics

When the fingertip catches the rotation axis of a ball, and the ball rotates at high speed, the ball does a steady rotation by the gyroscopic effect. Therefore, as one means because of no drop of the ball from fingertip, there is a method of beating the side of ball by hand when spin velocity slow down and torque the ball. But, we don't think about control to add torque a ball, because we focus attention on control the fingertip has a ball in this paper. In this instance, we think about control methods because of no drop of a spinning ball on fingertips by adding appropriate power to the ball by movement of the robot hand against inclination and movement of a spinning ball. We dynamically explain how to control the robot hand when the inclination of a spinning ball grows.

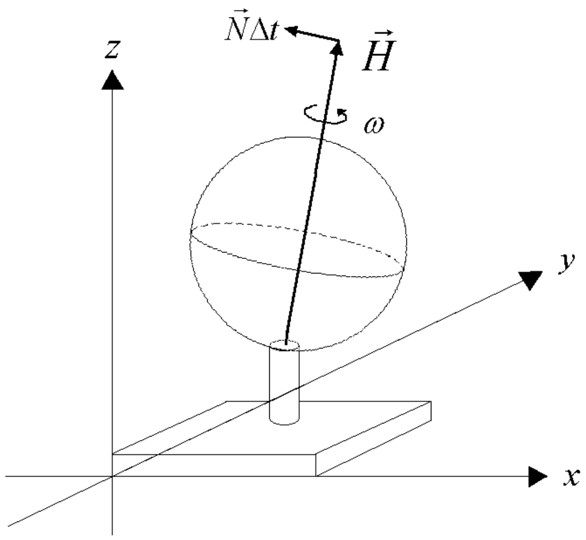

Fig.1 Control of Spinning Ball

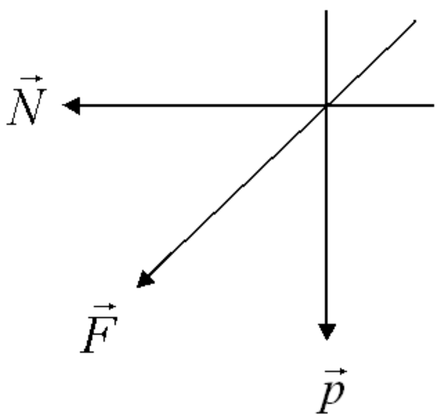

Fig.2 Relation of Vector

The $\vec{H}$ angular momentum vector of the ball that has inclined turns on the diagonal like Fig.1.

It is necessary to control this $\vec{H}$ to be suitable for a vertical direction to keep a steady rotation of ball. So, the following expressions are given,

$$\Delta\vec{H} = \vec{N}\Delta t \qquad (1)$$

At this moment, $\vec{H}$ is a variation in the angular momentum vector, and $\vec{N}$ is force moment. In a word, it has to add force moment $\vec{N}$ for this $\vec{H}$ to be suitable for a vertical direction. At this time, the problem to which direction to add force $\vec{F}$ is caused. Here, we assume position vector that to force point from gravity of ball is $\vec{p}$, as follows,

$$\vec{N} = \vec{p}\times\vec{F} \qquad (2)$$

At this time, the direction of three vectors is a relation of Fig.2. As a result, it is understood in which direction the robot hand should be moved for the inclination of the ball.

III. Control Model

In this section, we show the control model and planning of the robot hand for spinning control of ball, based on the spinning ball dynamics described in the foregoing section.

At the first, we show the model of the spinning control of ball in Fig.3. There is a cylindrical robot finger on the base where it can move on the x-y plane, and a ball on it. (x_p, y_p, z_p) is barycentric coordinate of robot finger, and (x_b, y_b, z_b) is barycentric coordinate of the ball. This robot finger is assumed to have the elasticity of rubber. When man has basketball by the fingertip, the fingertip that touches the bowl is transformed according to the shape of the ball. The fingertip becomes shape near the form of a cylinder rather than the oval, and the finger and the ball are in the state of surface contact.

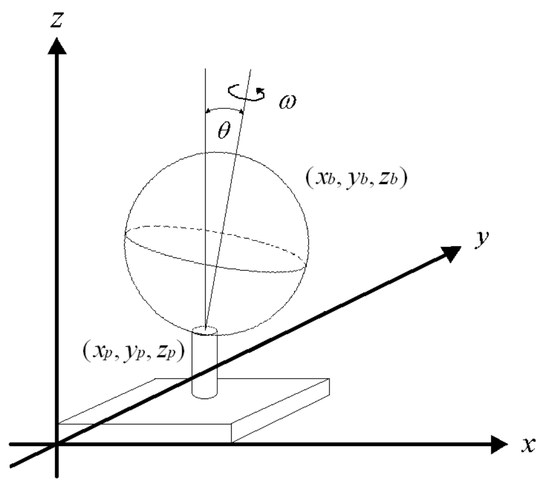

Fig.3 Control Model

We control the inclination and the barycentric position of the ball by the PID control. At this time, the state that spins with stability is not necessarily $\theta = 0$ in the spinning ball by movement characteristic. Therefore, it rather becomes unstable in the control planning that aims at deviation is 0.

Then, we set the following control rules. A downward moment from the center of gravity of the ball is shown in Fig.4. When this downward moment indicates the fingertip, the inclination is gradual. But when it indicates the outside of fingertip, the inclination of the ball increases at a dash. Then,

$$\theta \geq k_r \frac{180r}{R\pi} \quad (0 < k_r \leq 1) \tag{3}$$

to respond in this case, we did the control planning.

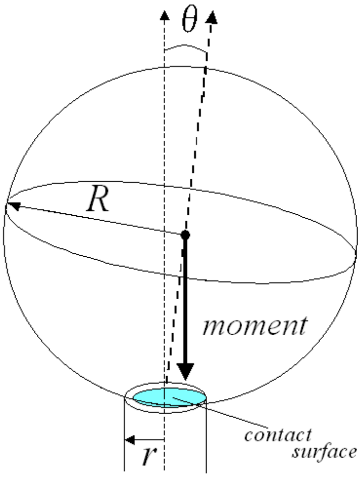

Fig.4 Moment of Ball

IV. Simulation

The result of the simulation is shown about the spinning ball model described in the foregoing section. Fig.5. is verification animation that we are used ODE and made, and Fig.6-8. is the result graph.

We set the parameter of the start of the simulati on at $\omega = 20rad/s$ (counterclockwise-rotation), $(x_p, y_p) = (x_b, y_b) = (0,0)$, $k_r = 0.5$.

In Fig.6, the angular velocity and the inclination of the ball are shown. And, x,y constituent of barycentric coordinate of robot finger in Fig.7, x,y constituent of barycentric coordinate of ball in Fig.8 is shown respectively. These graphs are shown that spinning speed of the ball fell at time, the robot hand is controlled without dropping the ball from the fingertip to the inclination of the spinning ball.

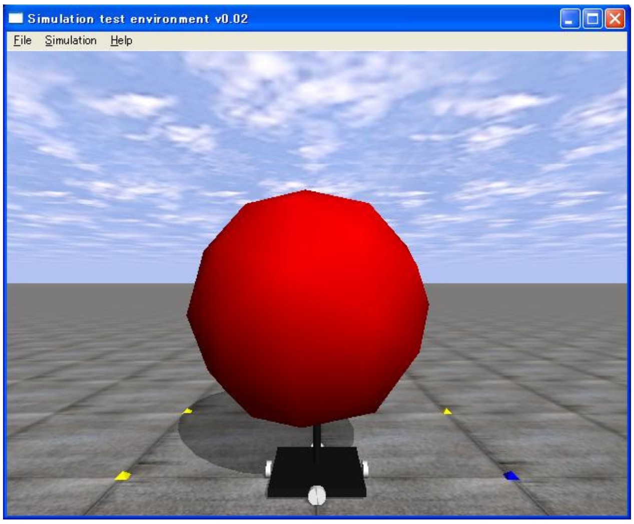

Fig.5 Animation by ODE

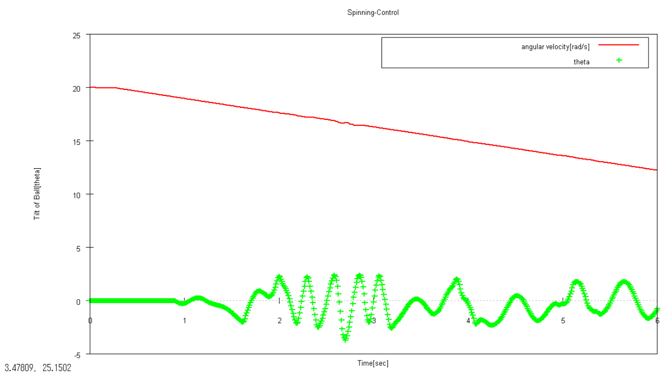

Fig.6 Angular Velocity and Inclination of Ball

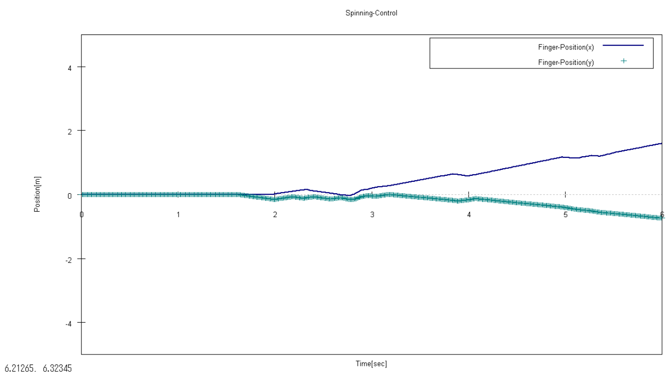

Fig.7 Excursion of Barycentric Coordinate of Finger

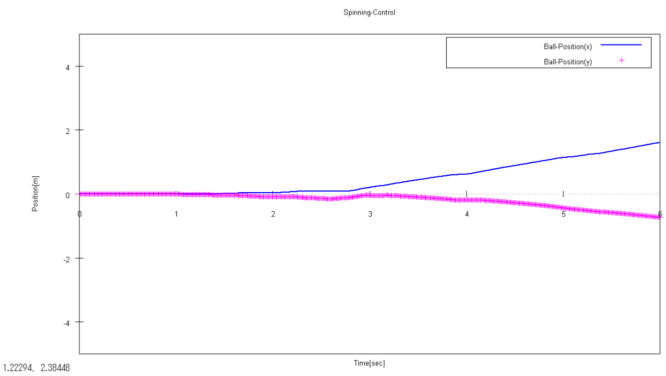

Fig.8 Excursion of Barycentric Coordinate of Ball

V. Conclusion

In this paper, we proposed control method of robot finger that manipulated a spinning ball as one example of dexterous manipulation by the robot hand, and verified by the simulation, and the effectiveness was shown. Consequently, we clarified whether to control the robot hand of the ball spinning that had not been discussed up to now like any. We can expect the achievement of the robot hand to be able to do a quick, appropriate correspondence by manipulating the movement of grasped object with the robot hand by the feedback control with stability. We plan to verify it by the real machine experiment in the future. But, we thought that it is a problem how to detect the inclination and the position of the ball changed at high speed for that accurately. In this time, we handled only the manipulation control of the spinning ball, we would like to think also about the control that gives the spinning force to the ball when the rotational speed of the ball descend in next time. Moreover, we thought that it is a problem that should also examine control method that think about the control of the vertical direction though we thought only about the control of horizontal direction this time.

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