

Kicking Testbed to Improve Kicks for Humanoid Soccer Robots in SPL

MING-LAN CHANG, N. Michael Mayer

Department of Electrical Engineering and Advanced Institute of Manufacturing with High-tech Innovations (AIM-HI), National Chung Cheng University, Chia-Yi, Taiwan
Email: nmmayer@gmail.com

Abstract. Kick motions are one of the major tasks in the humanoid soccer game. During the kicking process the most important thing is which part of the foot touches the ball in order to predict the ball's direction. We present a mechanism which can simulate kicks. For this purpose we built a kicking device as testbed. By using this machine we create a lookup table which records the kicking results and the relative position of the foot and the ball. We hope this data can improve the robot's skills such as in the case of dynamic kicks, perform a curved ball kick and predict the ball's direction.

1 Introduction

The kicking motion [1,2,3] is among the most important motions in the humanoid soccer game. Like other motion patterns, kick motions are designed by key frame based techniques [4, 5, 6]. This popular method has been used to design kick motions by a number of RoboCup Standard Platform League (SPL) teams. However, such approaches are inflexible, that is the robot cannot adapt with the changes of the situation, such as when the ball has been moved.

Although dynamic kick motions design is a formidable computational challenge [7,8,9], dynamic kick motions have become an important technique to improve the quality of the game. The intention is here to enable the robot to kick the ball in different directions with different force levels even if the ball has been moved to a different position while the robot is performing the kick (see Fig.1). This technique can save time if the robot is aiming to direct the kick or if the ball disappears while the robot is performing the kick. Dynamic kicking also plays an important role in passing challenge [10,11], the robot will modify the direction of the kick due to the position of the teammate, it lets the robot play more efficient on the soccer field. Approaches by B-Human and NaoTH [7,8] consider the foot contour as circle and thus simplifies the model of the collision between ball and foot as a collision between two spheres. This may lead inaccurate kicking results if the robot kicks the ball with one side of the foot.

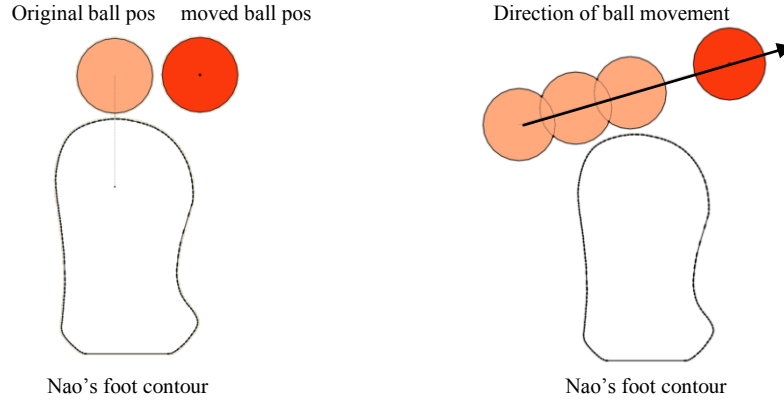


Fig. 1. The most common problems of kicking during the humanoid soccer game: The ball has been moved to a different position or the ball is rolling while the robot performs the kick.

In this paper we present a kicking device with the identical shape as real Nao's foot contour which can simulate the moment of the foot contour contact with the ball in any angle. We record the process with the camera to build up a lookup table of different foot and ball position pairs and results of the ball's direction after the kick. Unlike in the simulation, this data contains the factor of the torque the rolling ball and the friction between the ball, foot and field. The robot searches the lookup table every time before the kick to predict the ball. On the other side it can also let the robot learn how to predict the direction of a ball kicked by an opponent robot more precisely.

The paper is organized as follows: in section 2, we describe the elastic collisions to simulate the condition of the kick. Section 3 shows the structure and the mechanism of our device. The experiments and the results are given in section 4, section 5 contains conclusion and future works.

2 Elastic collisions

2.1 One-dimensional Newtonian

Collisions play an important role in analyzing and predicting the results of the kicking process. The Elastic collision between two objects 1 and 2, we let m_1 and m_2 be the masses, u_1 and u_2 the velocities before collision, and v_1 and v_2 the velocities after collision. According to the conservation of the total momentum the total momentum before and after the collision are the same. The equation is expressed as below.

$$m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$$

The conservation of the total kinetic energy is expressed by the equation as below.

$$\frac{m_1 u_1^2}{2} + \frac{m_2 u_2^2}{2} = \frac{m_1 v_1^2}{2} + \frac{m_2 v_2^2}{2}$$

We can find v_1 and v_2 by using the formulas above.

$$v_1 = \frac{u_1(m_1 - m_2) + 2m_2 u_2}{m_1 + m_2}$$

$$v_2 = \frac{u_2(m_2 - m_1) + 2m_1 u_1}{m_1 + m_2}$$

2.2 Elastic collisions in two dimensions

As shown in Fig.2, consider two objects, m_1 (blue) and m_2 (red). Assuming that m_2 is at rest before the collision, m_1 moves straight forward with velocity v_1 . The angle between \vec{v}_1 and \vec{v}'_2 is θ_1 , and the angle θ_2 is the deflection of m_1 after the collision. According to the conservation of the total momentum and the conservation of the total kinetic energy we get v'_1 and v'_2 as below

$$v'_1 = v_1 \frac{\sqrt{m_1^2 + m_2^2 + 2m_1 m_2 \cos \theta_1}}{m_1 + m_1}$$

$$v'_2 = v_1 \frac{2m_1}{m_1 + m_1} \sin \frac{\theta_1}{2}$$

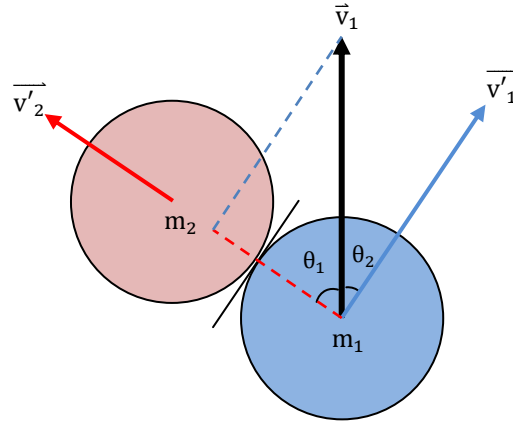


Fig. 2. m_2 is at rest before the collision, m_1 moves toward \vec{v}_1 . \vec{v}'_1 and \vec{v}'_2 are the moving directions of m_1 and m_2 after the collision respectively. Direction \vec{v}_1 , \vec{v}'_1 and \vec{v}'_2 form a right triangle indicated by dotted lines.

3.1 Hardware

In order to represent the foot shape of Nao precisely we build our device with the following hardware: Asus Xtion Pro Live, Makerbot Replicator 3D printer, squared iron shelving unit, extension springs, Dynamixel servo motors, and a laptop.

Asus Xtion Pro Live: With Xtion we can obtain RGB-D information, we scan around the Nao's foot sole with Xtion to build the 3D model of the Nao's foot contour in sketch up. In addition, we also use Xtion to record the process of the kick motion.

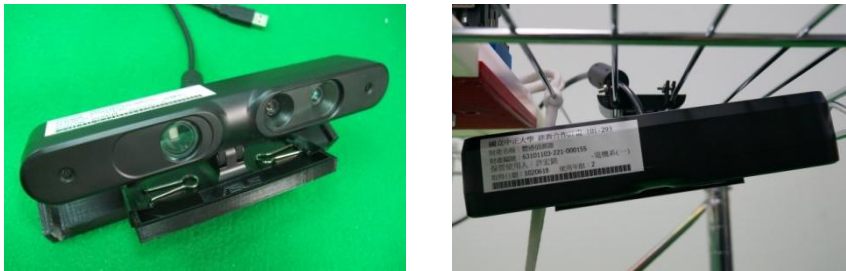


Fig. 3. Asus Xtion Pro Live RGB-D device and suspend on the top the frame.

Makerbot 3D printer: We print out the 3D model of the Nao's foot contour, ball and socket joint to represent the joint of the ankle and the hip, a trigger to launch the kick motion, and other small components to consummate the structure.

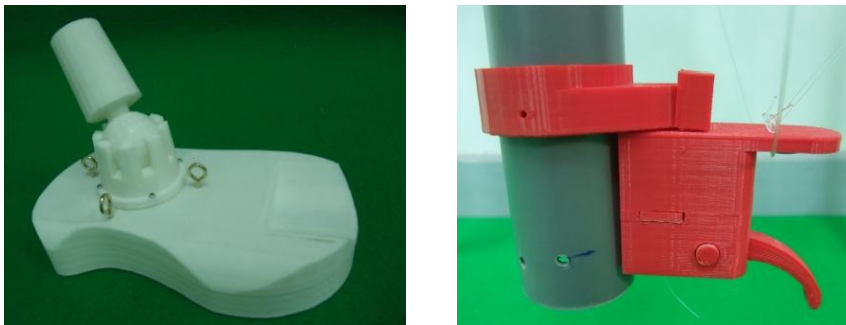


Fig. 4. Nao's foot contour with a ball and socket joint (left); one side of the trigger suspend on the foot and another side connect to the motors through the strings (right).

Squared iron shelving unit: A Squared iron shelving unit to form a robust outer frame whole device.

Extension Springs: Four extension springs suspend on four corners of the squared iron shelving unit, and on the other side of the springs all connect to the leg model of Nao.

Dynamixel servo motors: Two Dynamixel servo motors are connected to the leg model of the Nao by the enhanced nylon string. One motor controls the x axis motion of the foot model, and another controls the y axis.

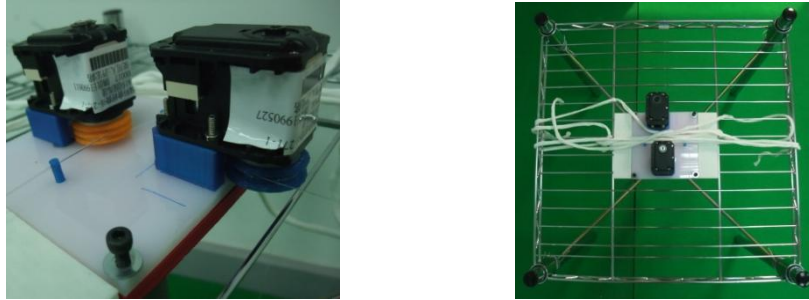


Fig. 5. Dynamixel servo motors control the foot through strings and are located at the center platform (left); the overview from the top, the springs connect to the four corners of the structure and the foot. In this way the kicking force is produced (right).

Laptop: The laptop provides the control of the foot model by sending and receiving packages to the servo motors, and also analyzing the data from Xtion sensor and build up the data base.

The overview of the device is shown in Fig.7. A tube with two ball joints at both sides forms the basic leg bone (see Fig.6). Usually we use two or three actuators to construct robot's ankle and the hip. We use ball and socket joints because ball joints have sufficient mobility to perform the kick in any angle. One side of the basic leg bone is attached to the squared iron shelving unit. The side of the basic leg bone is attached to the 3D model of the foot contour. Four extension springs suspend between the squared iron shelving unit and the basic leg bone to simulate the power of the kick. Two Dynamixel servo motors are connected to the basic leg bone with nylon strings. The Dynamixel servo motors pull the leg back and also left or right through enhanced nylon string to store the kicking force and the kick is prepared. After the trigger has been pulled the kick will be preformed. Xtion is set right above the foot where can record the moment of the kick.



Fig. 6. The basic leg bone represents the simplified leg of Nao.



Fig. 7. The overview of the device.

3.2 Software

The procedure of obtaining and analyzing the information from image is shows in Fig.8.

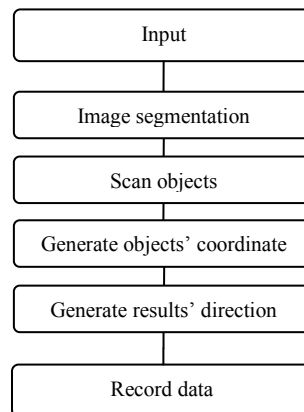


Fig. 8. Depicts the flow chart of the scanning software.

First the images are segmented into orange and white regions. Second we scan the segmented images to find the coordinates of the foot contour and the ball's center before the kick occurs. In order to determine the coordinates of the foot contour we have to find out the extreme right, left, top and bottom white pixels ($startW_v$, $endW_v$,

$midW_v$, $endW_h$). From these pixels we can find the semi- rightmost point ($endW_h$) of the foot. The final rightmost point is determined by scanning the rest of the right half image vertically until no white pixels can be found any more.

In a similar way we find the coordinate of the center of the ball. To find the orange pixel, first we scan vertically from the middle of the image, second we scan leftward column by column, if there is still no orange pixel can be found then we scan rightward. After finding the first orange pixel we scan vertically to get the last orange pixel in this scan line and then calculate the middle point of the orange pixels, i.e. the y coordinate of the ball center. We can get the x coordinate of the ball center in the same way.

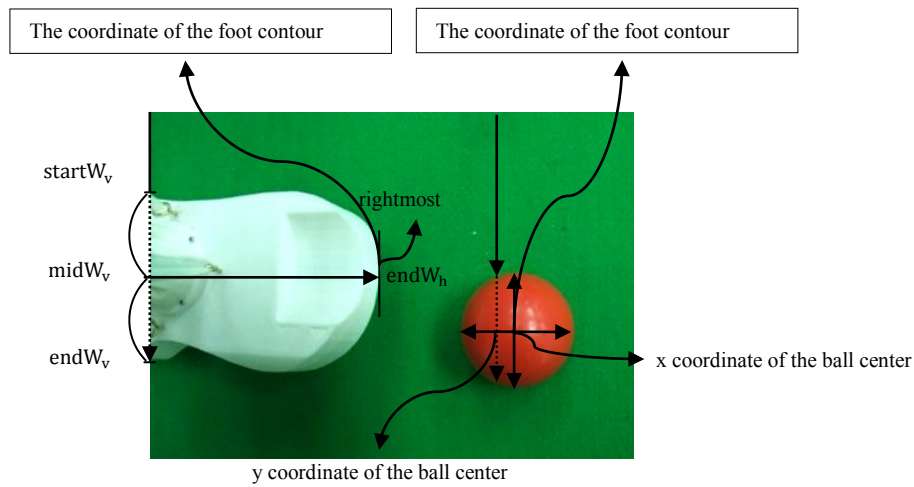


Fig. 9. The illustration of scanning the coordinate the foot contour and the center of the ball. Here we set an offset to speed up the scanning process.

After the kick we detect the center of the ball through the serial images with the same method. The direction vector of the moving ball is determined by the difference of the coordinates of the ball center in each frame. The coordinate of the foot contour and the ball's center before the kick and the ball's moving direction vector construct one group of data. We repeat this procedure several times with different ball positions to get the basic data set and create a lookup table to results of the ball's direction after the kick. The rest of the direction vector is calculated by using the interpolation.

The input of this lookup table is the position of the ball and the output is the result direction of the ball after the kick. Every time before the kick, the robot observes the position of the ball related to the robot itself and looks up this table to predict the motion of the ball more precisely.

4 Results

In this experiment we fix the direction of the kick and set the ball in different positions in each testing. The Fig. 10 shows one series of the raw kicking image with the ball's offset 14.2 and -7.3.

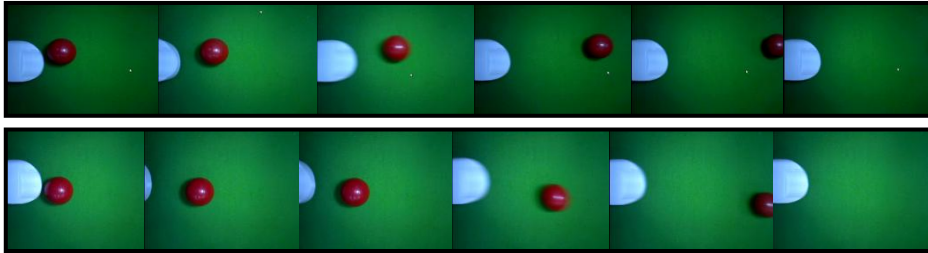


Fig. 10. A serial of raw image of kicking with the ball offset 14.2

Here ball offset represents the ball position in relation to the foot because of we fix the kick direction straight forward. The vector between two balls' center is the result for which we care most i.e. the direction vector of the rolling ball (see Fig.11.).

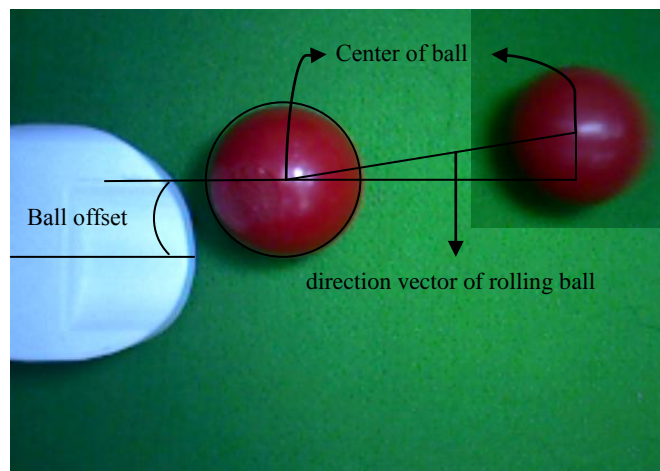


Fig. 11. Acquire information from the video

The Fig.12 shows the data set after several tests, and we calculate the reciprocal of the slope to simplify the result. It is also more obvious to observe. In Fig.13 the data of Fig.12 is depicted in a 2D image. We can find out the result is different from assuming the collision as an elastic collisions in two dimensions.

num	Ball offset	direction vector	slope	reciprocal of slope
1	-37.2	(14.1,-34.5)	-2.4467	-0.4087
2	-22.5	(14.2,-7.9)	-0.5563	-1.7975
3	-7.3	(43.0,-6.0)	-0.1395	-7.1667
4	-3.2	(93.3,-5.7)	-0.0611	-16.3684
5	-2.0	(62.9,2.0)	-0.0318	-31.45
6	-0.1	(43.4,-0.6)	-0.0138	-72.3333
7	14.2	(29.7,3.1)	0.1044	9.5806
8	17.0	(77.8,13.1)	0.1684	5.9389
9	31.4	(46.0,30.7)	0.6674	1.4984
10	35.4	(19.3,14.2)	0.7357	1.3592

Fig. 12. The data set of straight kick.

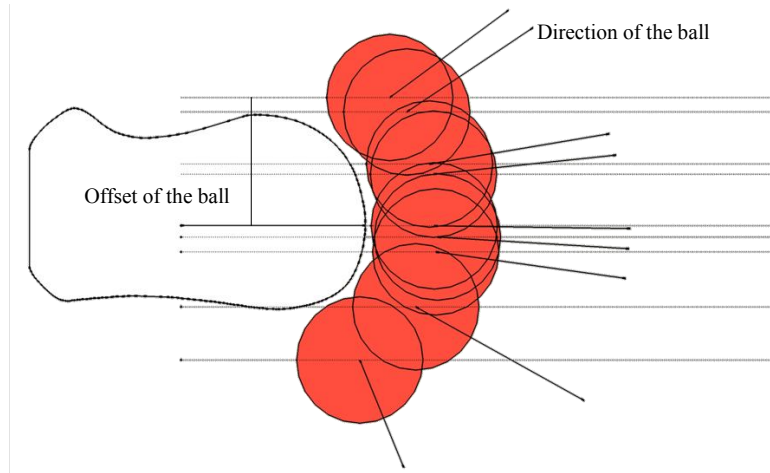


Fig. 13. A 2D illustration of the data set. The orange circles are the ball's positions in different offsets. The foot kicks straight forward.

The robot looks up the table to predict the result. If the offset of the ball is not found in the table, the robot will calculate the kicking result by using interpolation

$$\text{kick}_{\text{result}} = \frac{(\text{offset}_{\text{observe}} - \text{offset}_{\text{lower}}) \times (\text{resultSlope}_{\text{upper}} - \text{resultSlope}_{\text{lower}})}{\text{offset}_{\text{upper}} - \text{offset}_{\text{lower}}} + \text{resultSlope}_{\text{lower}}$$

5 Conclusion and Future Work

In this paper we present a device can perform the kick motion and also build up the lookup table of the kicking result. With this data, we want to improve the

performance of the kick. Before the kick looks up the table and modify the position of the foot due to the ball to make the kick more accurate at any time.

At this stage the data has been obtained and process on this device and the laptop. Further we want to build the system in the robot so he can learn and improve his kick skill in every soccer game. On another side, if the camera is set in different position to observe this device, then we can acquire the data just as the robot is observing the ball kick by opponents. This lookup table will be useful for the robot to enhance his ability of predict.

Last we will try to perform the different kicks from different directions to complete the lookup table and make the dynamic kick more perfect. In addition, it is also possible and interesting to perform a curved ball kick with this device [12]. The curved ball kick will have an impact on the soccer game.

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