Dynamic Ball Kicking for Humanoid Robots

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Abstract. *For soccer playing humanoid robots, the ability to kick a ball is as crucial as recognizing the ball and walking. However, in a more general sense, kicking a ball represents a sophisticated singular movement. In order to perform complex tasks in humanoid environments, it is necessary to handle dozens of these actions. Up to now, unlike for the periodic walking movements, these sequences typically have been 'scripted', i.e. fixed movements of the individual joints. This has been found to be inflexible and deficient. The kicking engine, described here, however, allows for dynamic real time calculation of kick movements and thus makes possible to adapt to the individual situations and objectives of the robots.*

1. Introduction

Scripted movement patterns are fixed pre-defined or, during a teach-in process, pre-recorded patterns of movement of individual joints of the robot. The transitions between successive patterns are then usually linearly interpolated so as to create a flowing movement. The major advantage in static motions is that simple movement sequences can be implemented fairly quickly, however adaptation of the movements, e.g. to account for mechanical differences of individual robots or different walking surfaces, require considerable effort. Further more, for every variation of a pattern, an equivalent motion had to be created. Nowadays dynamic walk engines for the periodic walking movements are state-of-the-art. They allow the robot to move in any direction with variable speed and to stabilize on different surfaces just by adapting some walking parameters.

The development of our kick engine is based on the similar idea of dynamically parameterized and controlled kick movements to replace the static kick sequence. Therefore, implementing many movement sequences and individually adapting them to different robots and environments is not necessary any more. From now on our robots have the potential to perform omnidirectional kicks. Similar to [1], the goal was to get more flexibility, but unlike initially without consideration of constraints like balance or collision. In contrast to methods [2] and [3] the calculation is kept simple and does not use bezir curves due to speed. A custom inverse kinematics is the basis for the implementation, as described in [4].

In this paper we focus on the actual movement of the kicking leg and do not consider the standing leg. Following this introduction, we shortly summarize the phases of a ball-kicking movement, then outline the development process and the functionality of the kick engine and end with a conclusion.

2. Phases of the Kick Movement

The general kick movement was divided into four basic phases: 'balance phase', 'swing-back phase', 'kick phase' and 'settling phase'. In the 'balance phase' the center of mass is shifted onto the support leg and then the kicking leg is raised (Fig. 1 a-c). Depending on the type of kick it fades to 'swing-back phase' in which the kicking leg is swung back to the swung-back position (Fig. 1 d). The 'kick phase' then produces the actual kick, accelerating the foot forward, ideally to the position of the ball (Fig. 1 e-f). For improved body control an additional 'kick-fade phase' can be introduced after the 'kick phase'. In this phase the leg is decelerated in a controlled way to reduce the jerky movement and related instability after the kick. Eventually, during the 'settling phase' the robot comes to a rest on both legs again (Fig. 1 g-h).

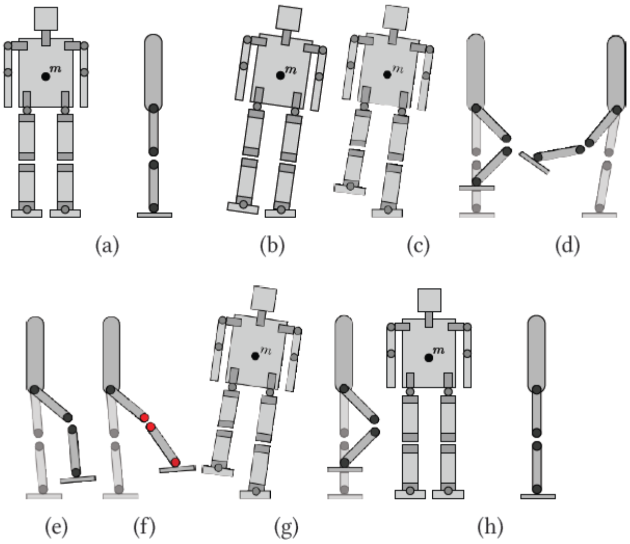

Figure 1. Phases of a kick

3. The Kick Engine

To get an overview of the possible movements and thus the basic parameters and their limits, the mechanical structure of our RoboCup kid-size robot platform was analyzed. This was based on previous work of the research group [5]. The kinematic model was derived and tested. The kick engine hides the details of the inverse kinematics from the user. In order to parameterize the kick, currently up to seven values out of eight may need to be provided for one of the five basic kick movements (Fig. 2). The high kick has not been finalized yet and may require additional parameters.

For a basic 'Kick Ball' the position of the ball (B) has to be provided as three-dimensional vector relative to the center of the robot. In our implementation, the individual components of the vector are represented by a signed short (16 bit integer) and are given in millimeters. This way, maximum lengths up to +/- 32.76 meters are presentable, which is sufficient for the upcoming RoboCup field size of 9 x 6 meters.

With the 'Kick Ball' movement, the kicking leg is accelerated along the regular leg trajectory. So if the ball is in front of the robot, the ball will move forward. However, if the ball is, for example to the left, the ball is played to the left side. This functionality is close to the static kick movement and is very inflexible. With more sophisticated movements availably, it is now only used in very few situations.

```
       == Kicker-Test ==
Ball x (mm)      115
Ball y (mm)       72             *
Ball z (mm)       46
Target x (mm)   1253
Target y (mm)     47
Target z (mm)    -34
Kicktype        2 (MEDIUM)
Fade enable     1


[1] Kick Ball           (B)
[2] Kick Ball Forward   (B,K)
[3] Kick Ball Backward  (B,K)
[4] Kick Ball Sideward  (B,K)
[5] Kick Ball to Target (B,T)
[6] High Kick (incorrect!)
[0] Cancel Kick
```

Figure 2. Test program

More flexible are the directed kicks that also allow control of the direction of the kick, to the front ‘Kick Ball Forward’, sideways ‘Kick Ball Sideward’ or backwards ‘Kick Ball Backward’. In addition, the impetus may be provided by the parameter ‘Kicktype’ (K), to control the distance the ball may travel. Currently, the values ‘minimal’, ‘short’, ‘medium’, ‘power’ and ‘maximum’ are implemented. Basically they control the speed when the foot hits the ball.

The most sophisticated, targeted kick function “Kick Ball to Target” is parameterized by the ball position and the target position, indicating where the ball should arrive. Based on vector analysis (Fig. 3) a specific swung-back or ‘backfoot’ position is taken before the kick is executed. However, for precise control of the direction, the ball travels, it is crucial that the foot, specifically the intended contact area, is properly aligned, i.e. in our case perpendicular or parallel to the target vector. Because of limited mobility and to avoid collisions between legs, not all combinations and ranges of parameters are realizable.

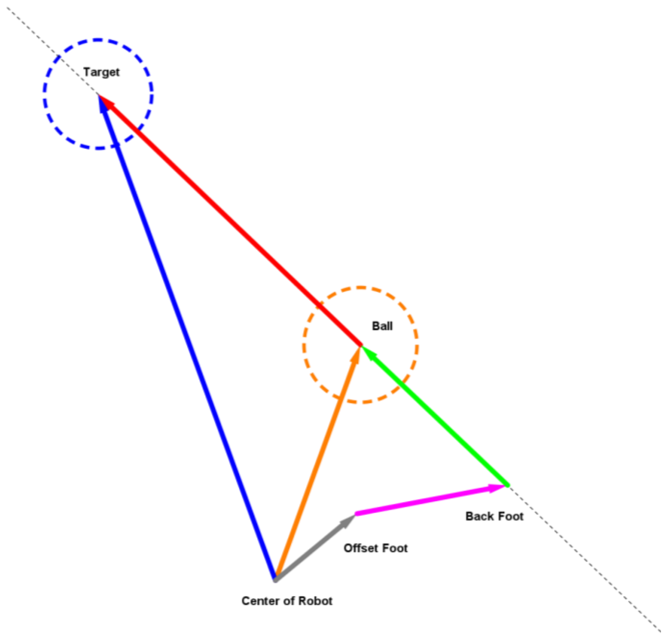

Figure 3. 'Kick Ball to Target' calculation

4. Conclusions

The basic kick engine has been implemented and tested on a number of robots, all with the same overall structure but with a number of minor deviations, e.g. in the individual joints and drives. It proved to be considerably robust with respect to these mechanical deviations. Environmental influences on the ability to kick, like the material and state of the surface of the playing field could be reduced significantly.

For the immediate future, the high kick as an important extension of the current basic kick engine and consideration of the support leg will be addressed. Further more, the increased abilities now need to be considered in the high-level control and decision process of the robots soccer-playing program. The improved body control may also be useful for robots to interact in a human environment and with humans. The dynamic kick engine can only be viewed as one of the first steps.

References

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