Learning residual dynamics for close control ball dribbling

Miguel Abreu[1], Luís Paulo Reis[1], and Nuno Lau[2]

[1] LIACC, FEUP, University of Porto, Portugal {m.abreu,lpreis}fe.up.pt
[2] IEETA, DETI, University of Aveiro, Portugal nunolau@ua.pt

Abstract

A humanoid robotic soccer team is only as good as its ability to retain possession and push the ball forward. The former concept requires close control of the ball, while the latter requires a blend of speed, agility, and high level strategy. Passing allows fast progression to the detriment of close control, while dribbling works in the opposite way. Up to this moment, the league has originated great kicking skills, that are both precise and powerful, being able to kick the ball beyond 18m. However, dribbling skills are still lacking in terms of speed and maneuverability. In light of this challenge, we propose a novel close control ball dribbling behavior.

The model architecture consists of three main components: a linear inverted pendulum (LIP) model, a shallow neural network, and a predictive controller. The LIP model is an analytical structure that allows the robot to walk in place. Its parameterization adapts the behavior to different step durations and other gait properties, such as the height of the swing leg, swing span, and stride width.

A shallow neural network is used to learn residual dynamics, i.e., the difference between the walk-in-place behavior and the dribble skill. The network is composed of only 1 hidden layer with 64 neurons. Its inputs are the state of the walk-in-place behavior and the robot, as well as the relative position of the ball. The outputs are the residuals of the relative position of feet and hands, which are later converted into joint target angles using inverse kinematics. Finally, these targets are fed to a 1-step predictive controller that takes into consideration the last action sent to the server. The optimization is performed by the Proximal Policy Optimization reinforcement learning algorithm, augmented by the Proximal Symmetry Loss [1] to leverage the robot's symmetry in the sagittal plane.

The dribble is able to achieve a maximum speed of 1.3 m/s, while keeping the ball at less than 10cm from the midpoint between both feet. For an 90 degree rotation, it has an average turning radius of 0.31m immediately after starting the dribble, and 0.59m if starting to turn at maximum speed.

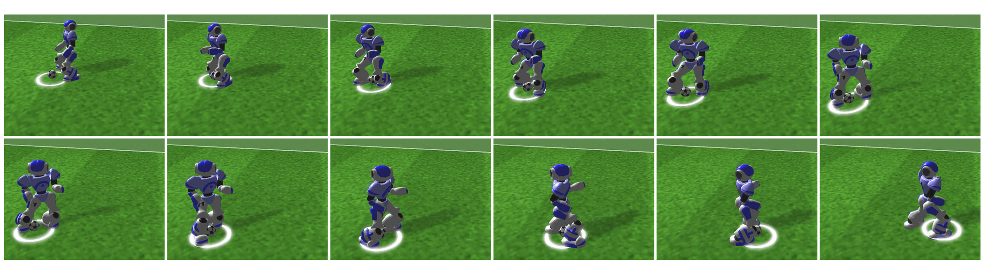

Fig. 1. Close control dribble, starting with a sharp left turn

References

1. Kasaei, M., Abreu, M., Lau, N., Pereira, A., & Reis, L. P. (2021). A CPG-Based Agile and Versatile Locomotion Framework Using Proximal Symmetry Loss. arXiv preprint arXiv:2103.00928.