Evolutionary Optimization of Walk Engine Controllers and Robot Morphology for Bipedal Running

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A key advantage of working with robots in simulation over working with robots in the physical world is the ability to quickly prototype and try out new robot models and behaviors. For this work we use evolutionary optimization to optimize both walk engine controllers and robot body morphologies for bipedal running.

We perform optimization in two different simulators: SimSpark[1] and Gazebo.[2] Both simulators use the Open Dynamics Engine (ODE) library for their realistic simulation of rigid body dynamics with collision detection and friction. The robots in the simulators are modeled after the humanoid Nao robot, which has a height of about 57 cm and a mass of 4.5 kg. Each robot has 22 degrees of freedom: six in each leg, four in each arm, and two in the neck.

In total 27 parameters for an omnidirectional walk engine controller [2] were optimized with the CMA-ES [1] algorithm to produce fast and stable running behavior. Additionally, in the SimSpark simulator, we optimized six anchor joint positions of the robot's body: the X,Y,Z offset values for the robot's hinge joints in its ankles, knees, and hips for a total of 18 additional parameter values. While it might be easy to gain performance in running by increasing the power and mass of a robot, we restricted our body changes to that of changing the anchor points of the robots joints. In doing so we hope to find ways of redesigning robots efficiently to maximize the potential of their current materials and motors.

Bipedal running is evaluated as the speed in m/s that a robot can run forward plus the percentage of time that a robot has both feet off the ground. This evaluation is based off a running robot challenge[3] held at the RoboCup 3D simulation competition in which autonomous simulated Nao robots play soccer against each other. Our RoboCup 3D simulation team, UT Austin Villa,[4] had the highest values for speed and off ground percentage, and won the challenge with a score almost 50% higher than the next competitor [3].

Videos of our robots using walk engine controllers and morphologies optimized for bipedal running are available online.[5] Interestingly the robot with both an optimized walk controller and morphology moves somewhat like an ostrich—ostriches are the fastest bipedal animals in the world. Most of the code we used in this work, including the parameterized omnidirectional walk engine and hooks for optimization, is available in a public code release [4].[6]

References

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[1] http://simspark.sourceforge.net/
[2] http://gazebosim.org/
[3] Details of the running challenge at http://www.cs.utexas.edu/~AustinVilla/sim/3dsimulation/AustinVilla3DSimulationFiles/2014/files/RunChallenge.pdf
[4] Team homepage: http://www.cs.utexas.edu/~AustinVilla/sim/3dsimulation/
[5] Videos of optimized robots at http://www.cs.utexas.edu/~AustinVilla/sim/3dsimulation/AustinVilla3DSimulationFiles/2017/html/running.html
[6] Code release at https://github.com/LARG/utaustinvilla3d