Smooth discrete feedback control of walking robots: An intermediate between fully passive and high bandwidth feedback control.

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Presented at World Congress on Biomechanics 2010, 1-6 August 2010.

There are two extreme schools of thoughts on controlling walking machines; passive dynamics based control and high bandwidth feedback control. Passive dynamics approach seeks to outsource the control to the mechanics of the machine. Passive elements like masses, springs, dampers, mechanical stops are insightfully placed in the morphology so that the robot can walk by relying exclusively on these passive components. There is absolutely no active control employed in this approach. Passive dynamic machines are generally energy efficient but have little stability and no versatility (e.g. walk fast, walk slow, turn). On the other hand, traditional feedback control (optimal/non-linear control) uses a model of the system to compute a control law, which is implemented at a high bandwidth on the prototype system. Some of these non-linear control methods are based on canceling the natural motions of the system, making such a control method energetically expensive while others like optimal control tends to be too computationally expensive and model dependent to be practically useful.

Here we propose an intermediate approach which we call 'smooth discrete feedback control'. In this approach, the control synthesis takes place in two stages. First, we approximate the open loop optimal solution to the control problem (like maximize energy efficiency) using simpler description and few numbers of parameters. Second, we choose minimal number of sections for feedback control, linearize the equations of motion about these sections and calculate and implement a smooth discrete controller to stabilize the system. The gains for the smooth discrete control are kept as small as possible by correcting only the unstable modes of the system. The resulting controller tends to be computationally less expensive and uses low sensor information while retaining the structure of the optimal solution. Some other advantages are that, this controller incorporates computation and sensor delays, can be made deadbeat (full correction of deviations), and is flexible enough to incorporate intuitive control ideas.