Dynamic walking simulations

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Passive Dynamic Walking

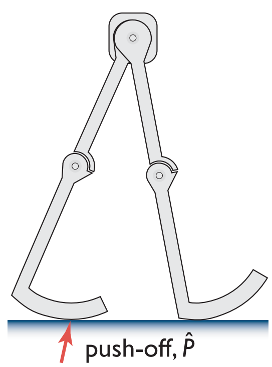
A simple mechanical linkage with no motors or control can be constructed to perform passive dynamic walking. It can descend a gentle slope with a periodic gait, or limit cycle, dictated by the dynamics of the legs (McGeer, 1990). Actuation can be added, for example to provide push-off at the ankle, for powered walking on level ground (Collins et al., 2005). Powered walking that still relies heavily on passive dynamics is referred to as *dynamic walking*.

Dynamic Walking Simulations

Following are computer simulations based on the same principles as the physical robots.

Walking with Push-Off

A push-off impulse is applied by the trailing leg immediately prior to heelstrike of the leading leg. The positive work counters the negative work of the heelstrike collision, resulting in a steady gait. Push-off is an economical means of powering gait, but only for a limited range of speeds.



Increased Push-Off

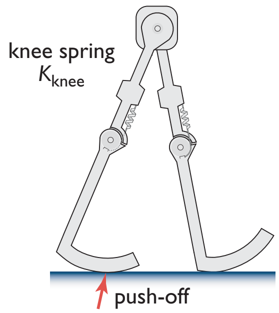
Greater push-off allows for only slightly more speed. Without any actuation about the joints, the model stumbles at the equivalent of about half of normal human walking speed.

References

McGeer, T. (1990). *Intl J Robot Res* 9: 62-82.
Collins, S., Ruina, A., Tedrake, R., Wisse, M. (2005). *Science* 307: 1082-1085.

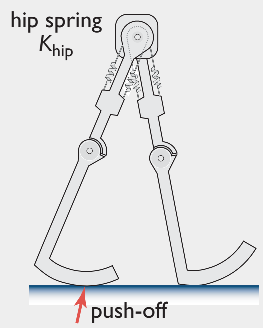
Knee Springs

Knee springs cause the model to walk more like a straight-legged model. Greater push-off may be applied without stumbling, allowing for higher speeds. The straighter leg does not provide ground clearance at mid-swing, resulting in foot scuffing. Bar graphs show joint torques due to springs.



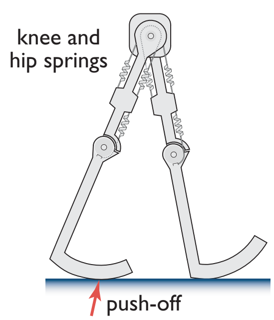
Hip Springs

Hip springs cause the legs to move faster, with higher step frequency. Walking speed is still limited, due to a mismatch between the faster motion of the thigh and the slower motion of the shank. Power still comes from push-off, but the spring modulates leg motion.



Knee and Hip Springs

Uni-articular springs about both the knees and hips allow for fast and economical walking. The knee spring makes the leg stiffer, so that the shank does not lag behind the thigh. The knee stiffness needed for faster walking also causes the leg to straighten before mid-swing, resulting in foot scuffing.



Bi-articular Springs

Bi-articular springs acting across both hip and knee allow for fast and economical walking, with good ground clearance of the swing leg. This gait requires a fairly narrow range of the ratio of hip and knee moment arms, beyond which the model stumbles. The swing phase joint torques resemble those for humans.