Bipedal Walking Research with the Humanoid Robot M2

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The Problem: To investigate biologically plausible control systems for the actuated humanoid bipedal robot, M2.

Motivation: 1. To develop further understanding of low-impedance control methods for locomotion in the real world with variable terrain and uncertainty. 2. To further understand the mechanical and control aspects of human locomotion. 3. To endow robots with similar locomotion capabilities as humans such that robots can replace humans in hazardous environments.

Humans have an incredible ability to locomote over varied terrain with great efficiency. Bipedal robots are a good platform for testing hypotheses on how humans control walking. They also provide insight into complex multiple degree of freedom systems. Finally, walking robots provide advantages over wheels in several situations like stairs and rough terrain.

Previous Work: Bipedal robots and human walking research have taken place in several different areas. Human biomechanics and locomotory characteristics have been studied and documented[1, 2]. There is a wealth of data on human walking motion and human structure[7, 8].

Several bipedal robots have been built by other research groups[3, 5, 10]. These have run and walked. Most of the walkers use high impedance control techniques which do not take advantage of the natural dynamics of the robot. Generally, the successful humanoid biped walkers have relied on pre-recorded or pre-computed trajectories to walk.

Passive dynamic ”robots” have been built[4] as well. These ”robots” have no actuators or electric sensors, but instead rely solely on the natural dynamics of the mechanical system. They are dynamic and stable, but there is no power input so they are limited to traveling downhill.

Previous work in the Leg Laboratory with Spring Flamingo[6] took advantage of natural dynamics in an actuated robot. Spring Flamingo is a planar bipedal robot with 6 actuated degrees of freedom using Series Elastic Actuators[9]. This research extends the work done on Spring Flamingo to the three dimensional case.

We surveyed existing human data and developed some basic size specifications for the robot M2. A minimum degree of complexity was chosen to accomplish the task of three dimensional walking. The robot has twelve actuated degrees of freedom and is sized after a 50th percentile human male(but lighter). There are three degrees of freedom at each hip, one at each knee, and two at each ankle. The robot weighs 62lbs without batteries, and 72lbs with roughly an hour and a half worth of NiMH batteries. This weight makes the robot manageable in a research environment, as opposed to a full weight adult human.

Approach: Rather than rely on lessons from early robotic arm research which suggest “stiffer is better”, our approach to robot control relies on softly pushing the system and allowing the natural system dynamics to determine the exact position trajectories. High bandwidth actuation can place the walking control problem in the same class as previously solved robot arm trajectory following problems, but data from humans and animals indicates that muscles are not actuated at high frequencies. Therefore, we are focusing our research on how to lower the bandwidth of the actuator signals in the robot and still maintain stability. We believe that this will not only be closer to the biological solution but should also be more robust to disturbances and terrain variations.

Difficulty: Mechanical actuators are different from human muscle, and current sensor and processing technology is different from sensing and processing on a human. The challenge lies in understanding when the different properties provide benefits and when they cause problems. Humans and other bipeds are incredibly robust in their ability to walk over just about anything. How can this be captured with the current actuator and sensor technology available to us? How does the structure of the robot help or hinder the design of walking control systems? How does the control system take advantage of the natural dynamics and still maintain stability? How well can we incorporate information from human subjects into control of the robot?

Future Work: This work can be extended with the addition of more degrees of freedom and high level sensor information, namely vision. Arms and torso movement certainly have an influence on walking and this work does not address that. Recovery from falls is also an area for future research.

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References:

[1] J. Rose and J. G. Gamble, eds. Human Walking. *Lippincott, Williams and Wilkins*, 1996.

[2] D. A. Winter. Biomechanics and Motor Control of Human Movement. *John Wiley and Sons, Inc.*, New York, 1990.

[3] J. Yamaguchi, A. Takanishi and I. Kato. Development of a Biped Walking Robot Adapting to a Horizontally Uneven Surface. *IEEE International Conference on Intelligent Robots and Systems*, pp. 1156-1163, 1994.

[4] T. McGeer. Passive Dynamic Walking. *International Journal of Robotics Research*, vol. 9, no. 2, pp. 62-82, 1990.

[5] H. Miura and I. Shimoyama. Dynamic Walk of a Biped. *International Journal of Robotics Research*, vol. 3, no. 2, pp. 60-74, 1984.

[6] J. Pratt and G. Pratt. Exploiting Natural Dynamics in the Control of a Planar Bipedal Walking Robot. *Allerton Conference on Communication, Control and Computing*, 1998.

[7] I. A. Kapandji. Physiology of the Joints, Volume Two, Lower Limb. *Churchill Livingstone*, 1998.

[8] Henry Dreyfus Associates. The Measure of Man and Woman. *Whitney Library of Design*, New York, 1993.

[9] G. A. Pratt and M. Williamson. Series Elastic Actuators. *IEEE International Conference on Intelligent Robots and Systems*, pp. 399-406, 1995.

[10] M. H. Raibert. Legged Robots That Balance. *MIT Press*, Cambridge, MA., 1986.

[11] D.W. Robinson, J.E. Pratt, D.J. Paluska, and G.A. Pratt. *Series Elastic Actuator Development for a Biomimetic Walking Robot.* IEEE/ASME AIM99, Sept 20-23, 1999. Atlanta, GA.

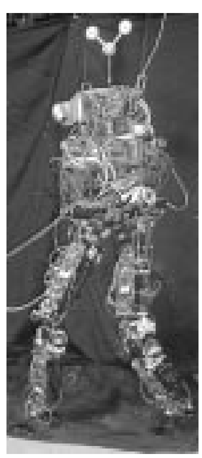

Figure 1: A photo of the robot M2.