01. Field of Study （専攻分野）

Research Topic

The Economy of Cursorial Motion

How the placement of leg joints in a bipedal humanoid affect the mechanical cost of generating force

Introduction

The cost of transport (CoT) is the measure of an object's energy efficiency as it moves from one point to another.[1] For humans the metabolic CoT of walking is about 0.1. (V. Radhakrishnan, 1998) Relative to other mammals, humans appear to be exceedingly economical walkers. Based on this observation, it is not unusual that most humanoid bipedal robots are built with the heel-down (plantigrade) foot posture. However, now that we have walking robots in various stages of development: Boston Dynamics' Petman, and Atlas Unplugged, Honda's Asimo, the RobotCub Consortium's iCub and Aldebaran Robotics' Nao, it's time to take a closer look at the economics of running robots.

In nature the fastest and most economical runners have either digitigrade or unguligrade foot posture, where the heel is held above the ground so the animal moves on the balls of its feet or toes, respectively. (C. B. Cunningham, N. Schilling, C. Anders, D. R. Carrier, 2010) With a 225 million year evolutionary head start over humans, the ostrich's foot design, which has fused the ankle and lower leg bones, (Jeremy DeSilva) a multitude of ligaments for joint stabilization (Nina Schaller), and unusually long tendons for reclaiming energy from each stride (Nicola Smith) seems to be the correct leg design to utilize if motor efficiency while running is the goal. Yet many of the currently available robots designed for running are built as either plantigrade or not bipedal at all.

Digitigrade and unguligrade postures improve locomotor economy by increasing stride length. (Myers, P., R. Espinosa, C. S. Parr, T. Jones, G. S. Hammond, and T. A. Dewey, 2016) If this applies to nature it should also have application in robot design. **My hypothesis is that a bipedal humanoid robot with digitigrade legs will have increased stable step length over currently available bipedal humanoid robots with plantigrade foot posture.** If this hypothesis is true, it would give this robot increased efficiency of motion making the mechanical cost of generating force more economical than existing robots of similar size and weight. This approach to the leg design of a humanoid bipedal robot is quite unconventional thus there is little research on the topic.

Although there is little research on the topic there are quadrupedal robots with digitigrade foot posture, bipedal robots with plantigrade foot posture, and robots classified as humanoid, researchers from any of these areas would provide valuable input for research that aims to combine them all. Studying in Japan will not only allow me to work closely with cutting-edge robotics professionals it would allow me to be immersed in a culture I admire and respect for it technological prowess and rich history in humanoid robotics. The opportunities and connections I'll have at a Japanese university far extend those I can receive at home universities because as someone who plans to have an international career beginning in Japan as a roboticist it makes the most sense to receive higher education in Japan.

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[1] **CoT** $\triangleq$ E/mgd = P/mgv where **E** is the energy input into the system, which has a mass **m**, that is used to move the system a distance **d**, and **g** is standard gravity. Alternatively, Power **P** can be input to move the system a constant velocity **v**. Wei Shi, Douwe Stapersma, and Hugo T. Grimmelius