Moving on Three Legs
— How to *imagine* and *control* non-biomimetic locomotion —

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Thiking of imaginary animals, or *Three-legged animals* in typical, is a stimulating idea. Although majority of mammal-sized animals have reflectional symmetry (left-to-right symmetry) in their body structure, we may discuss possibility of animals with essentially different structure, such as three-fold rotational symmetry. This idea leads us to some naive questions, e.g., how a three-legged animal would move if it existed or how it would develop from an embryo. One may also interested in evolutionary issue, such as their possible location in a phylogenetic tree: indeed, some fossiles with three-pointed structure were known to be found from Ediacaran period [1]). In this talk, the author presents some attempts to tackle the first question, i.e., show some *possible locomotion* by three legs, from constructive approach, with aids of rigid-body mechanics and control theory.

The *trident snake* [2], shown in Fig. 1, is a wheeled snake-like robot with three legs. Each leg is connected to the triangular base via an *active* joint, while a *passive* wheel is attached to the other end. Each wheel is supposed not to slide sideways, while the whole locomotion of the robot is modeled as a nonholonomic mechanical system [3] with three active control inputs. For this completely artificial (but somewhat snake-like) robot, the authors successfully derived control algorithms to generate fundamental locomotion patterns, as a result of mathematical controllability analysis. The key trick for control is coordination of sinusoidal control inputs, where balance of their phase gaps determines the choice between translational and rotational locomotion and/or moving direction. Apart from feedforward control, the authors suceeded in feedback control using reaction force from the ground, along the so-called *Tegotae-based control* approach proposed by Ishiguro, Owaki et. al. [4]

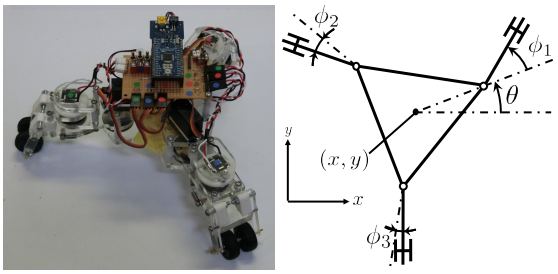

Figure 1: Trident snake robot

Another example of three-legged locomotion is *tripedal walking* [5, 6] shown in Fig. 2. On the left is a robot composed of a torso with three jointless legs fixed to it, and 2-d.o.f. active mass driver on top of the torso. It has no actuator in the lower part, thus the only driving force to the robot is the reaction torque (Yaw and Pitch) by the mass driver. On the right is a robot composed of a torso with three linear legs, while the legs are directly driven by linear actuators to stretch and shrink their lengths. Similarly to the case of the trident snake, the author showed that both of them can perform rotary and forwarding locomotion by choosing appropriate coordination of sinusoidal control inputs; however, since its behavior is more *dynamic* in this case, choice of the frequency becomes an important design parameter. The resulting locomotion is a complicated combination of *rocking* and *rolling*, where the rocking is excited by sinusoidal control, while the rolling of the spherical tiptoe induces planar locomotion as explained by mathmatical controllability analysis.

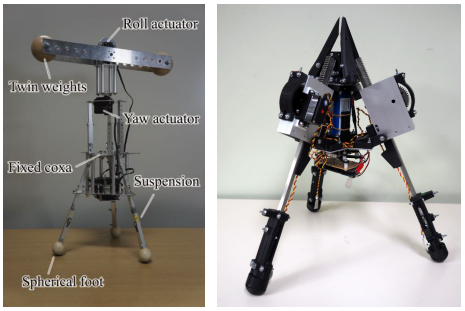

Figure 2: Tripedal walking robots

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