Which is Better?
A Natural or an Artificial
Surefooted Gait for Hexapods

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ABSTRACT

Natural multiped gaits are believed to evolve from countless generations of natural selection. However, do they also prove to be better choices for walking machines? This paper compares two surefooted gaits, one natural and the other artificial, for six-legged animals or robots. In these gaits four legs are used to support the body, enabling greater stability and tolerance for faults. A standardized hexapod model was carefully examined as it moved in arbitrary directions. The study also introduced a new factor in addition to the traditional stability margin criterion to evaluate the equilibrium of such gaits. Contrary to the common belief that natural gaits would always provide better stability during locomotion, these results show that the artificial gait is superior to the natural gait when moving transversely in precarious conditions.

Keywords: Artificial Diametric Gait, Hexapods, Paired Metachronal Gait, Surefooted Gaits, Walking Machines

INTRODUCTION

The topics of bio-mimetic robots have attracted much attention lately. There have been a variety of man-made bio-mimetic walking machines so far (Wang, 2010). Among them the six-legged types are popular designs, each often emulating some kind of crawling (McGhee & Iswandhi, 1979; Brooks, 1989), or running (Clark & Cutkosky, 2006), or even climbing insect (Palmer, Diller, & Quinn, 2009; Spenko, Haynes, Saunders, Cutkosky, Rizzi, Full, & Koditschek, 2008). Advantages for a robot to use the hexapod configuration (Figure 1A and 1B) are satisfactory walking efficiency and at the same time static stability. Hexapod gaits are much diversified, i.e., having a larger number of patterns than biped, quadruped or even myriapod gaits. A robot designer has to know which gait is the best for a specific use of the hexapod (Chu & Pang, 2002; Srinivasan & Ruina, 2006; Erden & Leblebicioglu, 2007; Starke, Robillard, Weller, Wilson, & Pfau, 2009).

Natural Gaits

There are apparently two broad categories of multiped gaits: natural and artificial gaits.
Natural gaits (Figure 1C) are those used by living creatures. For instance, Wilson (1966) has reported in his classic paper that the most common gaits for hexapods are the slow wave gait, the ripple gait and the tripod gait. Note that Wilson’s ripple gait was also referred to as the metachronal gait (Ferrell, 1993; Schreiner, 2004). Song and Waldron (1987) have developed a mathematical formula to theorize the natural gaits. This is possible since in a natural gait the legs on either side always move successively from the rear end to the front end of the animal (Wilson, 1966). Recently, some researchers have studied the metachronal gait of a stinkbug *Mesocerus marginatus* (Frantsevicha & Cruse, 2006) and that of a stick insect *Aretaon asperrimus* (Jeck & Cruse, 2007). As to transversely moving animals, the walking, trotting, and galloping gaits of the ghost crab have been investigated thoroughly (Full & Weinstein, 1992). However, the crab used an alternating tetrapod gait when it walks and trots, and a dynamically stable gait when it gallops with aerial phases.

Artificial Gaits

On the contrary, artificial gaits (Figure 1D) are created in the laboratory, only to be used by walking machines. The leg sequences of some artificial gaits, being too different from the natural gaits, cannot be expressed by Song and Waldron’s gait formula (Wang, 2010). The first artificial gait was a simulated wave gait developed by McGhee and Frank (1968) on a quadruped robot that crawled along a straight line. Shortly after that, a similar artificial gait for the hexapod machine was also developed (Bessonov & Umnov, 1973). As for the need for robots to conquer uneven terrain and obstacles, there have been the adaptive gait (McGhee & Iswandhi, 1979) and the FTL (follow-the-leader) gait (Ozguner, Tsai, & McGhee, 1984), which was pioneering obstacle-avoiding gaits. Recently, some non-periodic open-loop gaits were also proposed for climbing hexapods (Spenko, Haynes, Saunders, Cutkosky, Rizzi, Full, & Koditschek, 2008). These gaits, which require real-time feedbacks and much comput-