# Bio-inspired shape memory alloy actuated hexapod robot

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## ABSTRACT

This work presents the design and testing of a shape memory alloy and spring steel flexure actuator for use in a meso-scale, 18 degree of freedom hexapod. The paper discusses the general hexapod body design as well as a detailed design of the joints, actuators, and control methods of the individual hexapod legs. The performances of the control methods and of the hexapod legs are presented and discussed. Based on this measured performance, the expected rates of movement for different gaits are given.

Other work on SMA actuated walking robots differs in scale or environment. In the field of walking robots the use of SMA as an actuator is mainly limited to micro-scale applications, in which we consider robots measuring less than 5 cm in any dimension micro-scale. This work seeks to demonstrate that actuation with SMA is also possible and worthwhile at the meso-scale of robotics, the proposed robot measuring roughly 45 centimeters. A notable meso-scale SMA actuated walking robot, the RoboLobster, differs from this work in intended environment. The RoboLobster, designed to operate in shallow ocean water, benefits from its environment through cooling for the SMA actuators which improves cycle time (Ayers [1]). This robot also differs in leg number, possessing eight legs over the six of a hexapod. A final group of meso-scale walking robots, hexapods and otherwise, are actuated by smart materials other than shape memory alloys, including piezoelectric actuators (Goldfarb [2], Yumayanto [3]).

**Keywords:** robotics, hexapod, bio-inspired, shape memory alloy, smart materials

## 1. INTRODUCTION

In the world of walking robots, hexapods are a favorite for academic study and for hobbyists. Compared to other legged robots such as bipeds and quadrupeds, they are easier to balance statically and provide a number of possible gaits for study. Hexapods are also often created to mimic and study the movements of insects such as the cockroach, cricket, and praying mantis. Although biological inspiration is often cited as a motivator for hexapod study, the majority of hexapod robots utilize actuation methods, predominately servo motors, which are decidedly not comparable to biological actuation methods. Two methods currently exist which closely model the biological actuation of the muscle. The first is a pneumatic artificial muscle, sometimes called a McKibben muscle (Colbrunn [4]). The muscle is formed of an elastic tube which is constrained from lengthwise extension. When the tube is pressurized its circumferential expansion creates a lengthwise contraction capable of exerting a load on the connected frame. However, a prime drawback in the use of pneumatic artificial muscles is the necessity for high powered pumps capable of pressurizing and regulating fluid flow.

The second method is the use of shape memory alloy, usually abbreviated as SMA. The most commonly used SMA is a nickel-titanium alloy which possesses superior mechanical properties in comparison with copper based SMA. When the SMA is electrically driven or heated to a specific transition temperature, the atomic structure rearranges, causing a four to eight percent contraction in overall length. The SMA is capable of exerting large forces and transitioning between phases over thousands of cycles. For this reason SMA was chosen as the actuation method of the hexapod robot.

## 2. THEORY

### 2.1 Shape Memory Alloy

Due to its useful mechanical and electrical properties shape memory alloy has a history of use as a robotic actuator. The following section reviews the properties of SMA which are important to this work and gives examples of previous work which have utilized SMA as a robotic actuator.

The most pertinent property of shape memory alloy is the temperature controlled phase transition between its two crystalline structures, martensite and austenite. The martensite phase occurs when the SMA is below the phase transition temperature. As the temperature of the SMA material increases, through either conductive or electrical heating, the

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