Arque

Artificial Biomimicry-Inspired Tail for Extending Innate Body Functions

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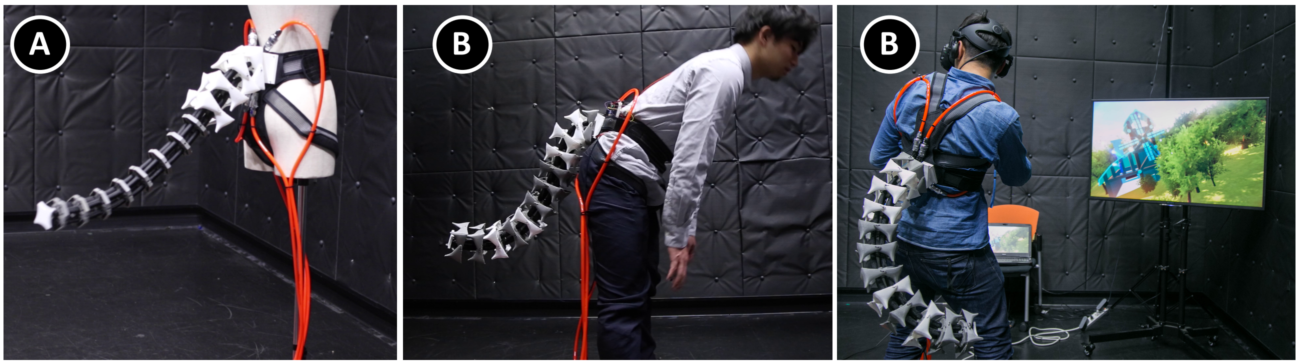

Figure 1: An overview of Arque, (A) an artificial bio-mimicry tail for on-body force presentation that allows to (B) provide active balancing to the wearer, and (C) can be used as haptic feedback to present virtual forces.

ABSTRACT

For most mammals and vertebrate animals, tail plays an important role for their body providing variant functions to expand their mobility, or as a limb that allows manipulation and gripping. In this work, Arque, we propose an artificial biomimicry-inspired anthropomorphic tail to allow us alter our body momentum for assistive, and haptic feedback applications. The proposed tail consists of adjacent joints with a spring-based structure to handle shearing and tangential forces, and allow managing the length and weight of the target tail. The internal structure of the tail is driven by four pneumatic artificial muscles providing the actuation mechanism for the tail tip. Here we highlight potential applications for using such prosthetic tail as an extension of human body to provide active momentum alteration in balancing situations, or as a device to alter body momentum for full-body haptic feedback scenarios.

CCS CONCEPTS

• **Computer systems organization** → **Robotics**; • **Human-centered computing** → *Haptic devices*;

KEYWORDS

Artificial Tail, Biomimicry, Biomechanics, Embodied Robotics

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1 INTRODUCTION

The tail is an organ commonly held by many vertebrate animals, and the role played by the tail varies depending on animals. At the same time, however, the tail has a common role to control the sense of equilibrium. When a cat loses its balance, it controls the center of gravity by swinging the tail [Walker et al. 1998]. In addition, capuchins who carry objects by biped locomotion actively control the tail, plus the tail and its extension become an essential role for balancing the body during load transport [Massaro et al. 2016]. Thus the tail becomes an active limb similar to the arms and legs with its dedicated functions.

Mankind considerably changed the form of their pelvis in the process of quadruped locomotion with the ease of stability of our center of gravity, and upright biped locomotion [Gruss and Schmitt 2015]. On the flat ground in everyday life, there is no shortage in maintaining the equilibrium of the body, but it becomes difficult to demonstrate the balancing ability in environments with poor footing. Also, vestibular sensory end organs gradually worsen with aging, and there is also a problem that old people tend to fall over easily [Zalewski 2015], resulting in potential damage to their body. What if our bodies were capable of integrating a functional tail to emulate some of the functions presented in nature, or even use it for different scenarios.

In this work, we demonstrate an anthropomorphic tail device that is capable of presenting forces to our body as shown in Figure

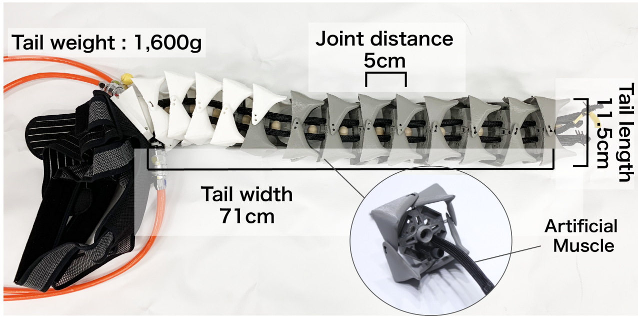

Figure 2: Proposed artificial tail structure, and an individual vertebrae with four embedded pneumatic artificial muscles.

1. Also, the design of this proposed tail is fluid and customizable in length to present varies degrees of forces to the center of gravity of our body. We show here some possible applications for body augmentation, or as an ungrounded haptic feedback device.

2 RELATED WORK

Previous research has investigated the methods and approaches to alter body structure through artificial wearable robotics. For example, Sixth-Finger [Prattichizzo et al. 2014] explored the use of an extra artificial finger to enhance hand's grip. [Saraiji et al. 2018] proposed an approach to increase the number of arms by substituting legs to artificial limbs. Furthermore, research on artificial tail interaction has also explored some potential applications for integrating the tail into our body, which was mainly for expressive applications. GIO [Ujima et al. 2015] used electromyography (EMG) sensors that were attached to the buttocks muscles to control the tail motion. Shippo[1] used electroencephalogram (EEG) signals to detect some basic emotions (surprise, sad, anger, ...etc) to actuate an artificial tail accordingly.

Here, we are focusing on the use of the tail as a body extension that passively provides forces for balance applications, or as a momentum haptic actuator.

3 PROSTHETIC TAIL DESIGN

The design of the proposed tail is highly inspired by the structure of the seahorse tail. The tail should have a weight adjustable design to accommodate different body weights. To present the thrust that affects the change in the center of gravity of the user, it is required that the tail unit has enough weight to alter the momentum (about 5% of body weight).

The model used in this work was inspired by the plate and vertebral design modeled with reference to existing studies [Porter et al. 2015]. In this prototype, the tail unit consists of a variant number of joint units to produce. Each joint consists of four protective plates and one weight adjustable vertebrae. At each joint, the plates are linked together using elastic cords, while the vertebrae are attached to them using a spring mechanism to mimic the resistance to transverse deformation and compressibility of a seahorse skeleton, and also to support the tangential and shearing forces generated when the tail actuates. Each vertebra embeds four chamber slots to insert the artificial muscles into them as shown in Figure 2. The four muscles used in this design allow controlling the tail along with eight different directions. Air compressor with up to 0.8 Kpa is used to actuate the muscles.

[1]http://neurowear.com/projects_detail/shippo.html

4 APPLICATIONS

4.1 Limb for Body Balance

We consider the role of the tail the improvement of equilibrium maintenance capability. In this application, the force generated by swinging the tail can change user's center of gravity position. A wearable body tracker mounted on the upper body of the user estimates the center of gravity, and accordingly actuates the tail. Figure 1 (B) shows the case of using the tail mounted on the waist of the user to alter the balance.

4.2 Full-body Haptic Feedback

A different approach for using the tail other than equilibrium maintenance is to change the center of mass of the user to off-balance posture. This can help to generate full body forces depending on the point of attachment of the tail, and can be used with applications such as in virtual reality. Also, one of the main benefits of using a tail to achieve such experience is the tail considered as an ungrounded system, and does not requires external mounting point. In Figure 1 (C) the tail is attached to the back of the user to provide momentum changes on the upper side of the body when the user experience strong virtual wind in virtual reality.

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