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Bird-inspired foot and limb for perching drones preliminary considerations

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Abstract

The aim of perching drones is to access the environment in a lot of locations for recovery operations, exploration and surveillance. The main challenge is to build a lightweight mechanism that can be easily mounted on the drone allowing to perch stably on a variety of natural substrates. A lightweight modularized and actuated landing gear framework stabilizes the drone on a wide range of structures by perching and resting [1]. The mechanical framework is inspired by claws of birds but the anatomy of the whole body is not taken into account. A dynamic model reveals how birds stabilize their grasp depending on surface asperities [2]. The model shows how birds can grasp complex surfaces but the role of each finger for perching stably is not investigated.

It is therefore essential to know how a drone can perch on a branch whatever the geometry, the surface and how it can remain stable despite external disturbances. We take inspiration from the anatomy of birds to optimize the interaction of drones with the environment. We describe thanks to preliminary considerations how combining: (i) the foot configuration (ii) the arrangement of tendons and (iii) the toe pad surface, we will construct a bioinspired perching drone. We used video acquisitions of living birds in 3D with high-speed cameras for preliminary experiments and we studied the anatomy of bird's foot and limb.

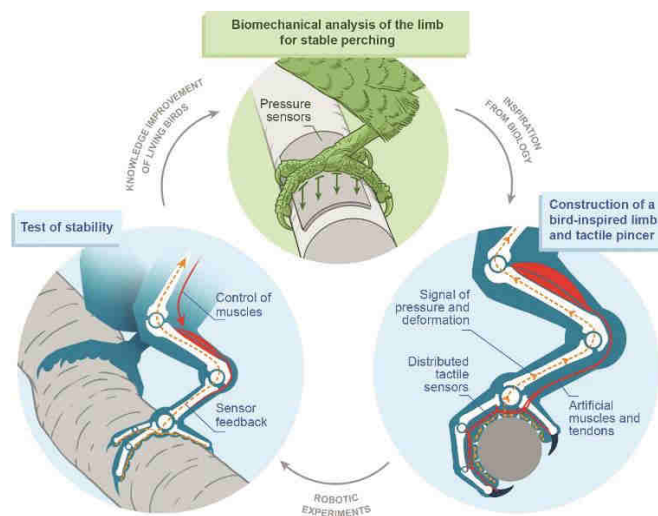


Figure 1: Illustration of the method to construct bioinspired foot and limb. (1) Biomechanical analysis of the limb for stable perching from living birds using pressure sensors and video acquisition in 3D with high-speed cameras (2) Construction of a bird-inspired limb and tactile pincer using artificial muscles, tendons and smart material for the active skin, (3) Test of stability of the robotic foot and limb using feedback control laws.

Results

Four toes foot configurations allow perching birds to maintain their stability.

The diversity of avian feet has long stood as a textbook example of adaptive variation. However, twelve different configurations exist, according to the number and arrangements of the toes [3]. Three general types of foot amongst birds: (1) the perching type; (2) the walking type and (3) the swimming type [4,5]. The basic adaptation for perching is a strong grip thanks to opposing sets of toes in order to encircle the branch [3]. The morphology of the foot has an influence on the ability to perch [6]. Five configurations of four toes foot lead to good grips [6], yet the participation of each toe is still unknown. Our aim is to quantify the effort at individual toe level, we have carried out experiments on the Kea parrot, as a test experiment to be able to adjust our protocol.

Flat toe pads enable better grasping of perches.

The toe pad surface is the interface between a bird and the object within its grasp (e.g. landing substrate, targeted prey or food item). The passerines (such as corvids and parrots) flat toepads enable them to walk and to perch or grasp, while the raptors have higher toepads to grasp their prey [7]. We will look at the foot plantar surface to design and construct an active skin for the tactile pincer.

Two tendons in the flexor muscles are decisive for perching birds.

The variety of arrangement and interconnections of the tendons of the bird deep digital flexor muscles was already described [8]. The tendons of the deep digital flexor muscles (*flexor digitorum longus* and *flexor hallucis longus*), inserted on the distal phalanx are determinant in grasping or carrying [3]. These two deep plantar tendons are classified in eight types of arrangements which can allow adaptation to perch. The proximally inserted tendons play a greater role in generating the requisite forces for perching behavior as demonstrated by simulations in 2D in [9]. We will test this configuration in our model.

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