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In Brief: Practice and Procedure

Developing biorobotics for veterinary research into cat movements

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ABSTRACT

Collaboration between veterinarians and other professionals such as engineers and computer scientists will become important in biorobotics for both scientific achievements and the protection of animal welfare. Particularly, cats have not yet become a significant source of inspiration for new technologies in robotics. This article suggests a novel approach for the investigation of particular aspects of cat morphology, neurophysiology, and behavior aimed at bridging this gap by focusing on the versatile, powerful locomotion abilities of cats and implementing a robotic tool for the measurements of biological parameters of animals and building cat-inspired robotic prototypes. The presented framework suggests the basis for the development of novel hypotheses and models describing biomechanics, locomotion, balancing system, visual perception, as well as learning and adaption of cat motor skills and behavior. In subsequent work, the resulting models will be tested and evaluated in simulated and real experiments and validated with specific experimental data gathered from cats. This methodology has application in several areas including dynamic models and artificial vision systems. From an ethical point of view, this approach is in line with the 3R principles: the detailed and integrated systems will allow us to study a small number of cats (reduction) for the implementation of noninvasive tools such as electromyography and gaze analysis (refinement), which will make the construction of a substitute to experiments on living cats (replacement) easier. For instance, bioinspired prototypes could be used to test how specific visual and physical impairment in cats (up to partial or total blindness, loss of a leg, and so forth) change their walking and jumping abilities. This modus operandi may pave the way for a new generation of research in the veterinary field. Moreover, the measurement tools to be developed will constitute an achievement per se as for the first time visual, muscular, and gait analysis of cats will be integrated, and this will help to improve the rehabilitation procedures for cats and other nonhuman animals.

Introduction

Biorobotics can be defined as the intersection of biology and robotics (Webb, 2001). Research involving bioinspired and biomimetic models has become increasingly relevant to both biology and engineering, with applications to industrial design. In particular, over the past decade the use of bioinspired robotic models in biological research has been rapidly increasing for various reasons. From a biological perspective, robotic prototypes modeling living systems perform 2 major functions: validation of a conceptual understanding of physical, behavioral, and sensomotoric processes (Long et al., 2006; Lauder et al., 2007; Phelan et al., 2010) and exploration of biological parameter spaces (Doorly et al., 2009). Physiological systems can be replicated using biorobotic structures that attempt to match their functional materials, structural, mechanical, electrical, and fluidic properties. Once a suitable model has been established, it can be used to address numerous

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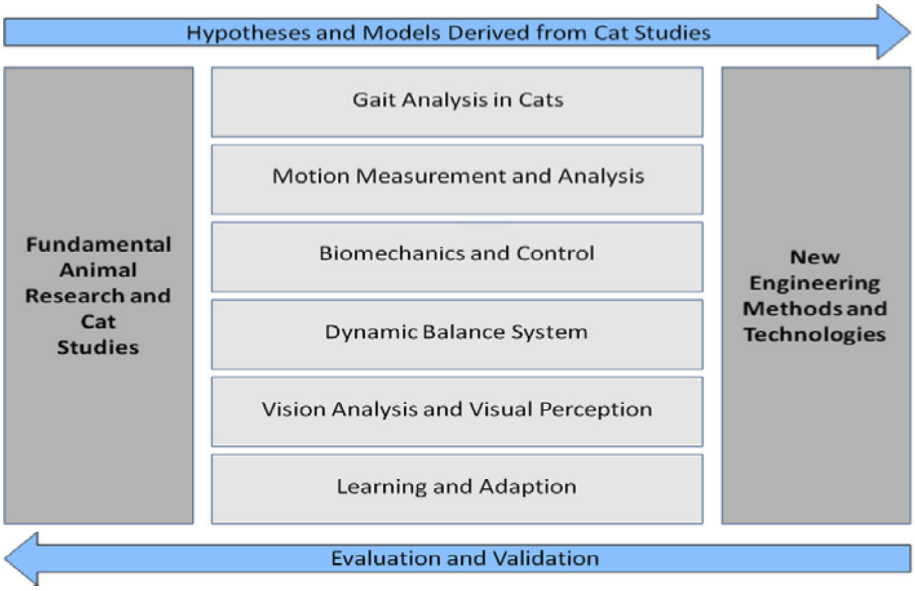

Figure 1. Scheme of the proposed approach.

scientific questions, some of which would be nearly impossible to investigate by solely relying on a living biological organism, repeatedly performing the analyzed behavior.

With the appropriate robotic prototype, scientists can replicate the desired kinematic pattern and examine the motion in simplified terms (Phelan et al., 2010) or produce a motion that fills a parameter space that cannot be observed under normal conditions (Long, 2007). Such an approach has already been used for swimming (Richards and Clemente, 2012) and flying (Lehmann et al., 2010) of animals and for human walking (Seyfarth and Geyer, 2002), running, and jumping (Radkhah et al., 2011).

The synergies between different professionals (e.g., biologists, veterinarians, computer scientists, and engineers) emerge during the construction of bioinspired and biomimetic robotic prototypes. The importance of veterinarians in all stages of such studies is obvious, as this professional has the crucial role of planning, monitoring, and interpreting research results involving animals, and similarly important, veterinarians are in charge of animal welfare protection.

Animal experiments are often associated with pain, fear, and/or suffering and do not directly benefit the research animal (Rusche, 2003). In the United States, more than 20,000 cats are annually used for research, and almost half of them are involved in research causing them pain (United States Department of Agriculture, 2010). Hence, many animal welfare associations demand the immediate abolition of all animal experiments, whereas from the perspective of those who allow animal experiments, the benefits of the research outweigh the animal suffering. To alleviate this situation, one of the focal points of veterinary and biology research should be the establishment of novel technologies and ethical procedures that reach the same scientific goals, while using fewer animals, reducing their suffering, or without using animals at all. These are the so called 3R principles: (replacement, refinement, and reduction; Russell and Burch, 1959). Robotics can be an extremely convenient tool to attain this aim. The symbiotic interaction of robotic technologies with veterinary and biology researchers has recently been shown to yield good results (Holmberg and Pelletier, 2009).

In this article, we describe a novel approach combining robotics and veterinary research, a long-term vision that depicts the use of novel robotic devices as substitutes for real cats in neurophysiological studies, thereby avoiding surgical modifications and the consequent impairment of cats. We propose a replacement technology that is completely noninvasive for the measurement of biological parameters and to develop cat-inspired robotic prototypes. Such prototypes could provide both the capability to execute realistic complex motions as well as full knowledge over cat egomotion, significantly aiding complementing research by evaluating and validating hypotheses and models derived from cat studies and, finally, probably even becoming a substitute for living cats in behavioral and neurophysiological experiments. It should be noted that the development of cat robot prototypes with such muscular-skeletal functionality and behavioral capabilities will also significantly advance the state of research in robotics.

Until now, research on cat locomotion has required invasive monitoring and/or the experimental impairment of cat functional structures. We propose a novel paradigm for the behavioral, neuroscientific, kinematic and dynamic analysis of cats (Figure 1). A new complementary set of integrated measurement tools should be used to monitor the physiological parameters of interest following a noninvasive approach; in particular, techniques can be adapted for the measurement of electromyographic (EMG) signals and gaze and head movements. A novel, noninvasive cat motion measurement and analysis tool that integrates multimodal data obtained from external and on-body measurements needs to be developed. The monitoring of these parameters, together with the analysis of all jumping and landing forces, and a reconstruction of the body movements by a motion capture system will provide the basis for a deepened understanding and modeling of the behavioral and sensomotoric abilities and control architecture that can be translated into design guidelines for the development of novel robotic cat prototypes.

These bioinspired robotic prototypes will open up a wide amount of novel possibilities for robotics as well as veterinary research in full compliance with the 3R principles. Prototypes will also allow researchers to test whether and how specifically visual and physical impairment in cats (up to partial or total blindness, loss of a leg, and so forth) modify their abilities to walk and jump, without using live animals. Moreover, we aim also to investigate technologies for noninvasive EMG and gaze analysis that can open new ways in veterinary practice for the benefit of the research and animals.