Commun Nonlinear Sci Numer Simulat 16 (2011) 2254–2264

Contents lists available at ScienceDirect

Commun Nonlinear Sci Numer Simulat

journal homepage: www.elsevier.com/locate/cnsns

Adaptive control of vibrissae-like mechanical sensors

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ARTICLE INFO

Article history:
Available online 4 May 2010

Keywords:
Mechanical systems
Bio-inspired
Adaptive control
Modeling

ABSTRACT

This paper is a contribution to the modeling and the adaptive control of bio-inspired sensors which have the animal vibrissae as a paradigm. Mice and rats employ a sophisticated tactile sensory system to explore their environment in addition to their visual and auditory sense. Vibrissae in the mystical pad (region around the mouth) are used both passively to sense environmental influences (wind, objects) and actively to detect surface and object structures. Inspired by this particular version of tactile sense we consider the following three stages of a sensory system: perception, transduction and processing of information. We model this system in combining two existing mechanical models and obtain an uncertain nonlinear control system. An applied adaptive controller implements the ability of the animals to employ their vibrissae actively as well as passively. Numerical simulations show that the developed nonlinear model compensates noise signals and reacts strongly to sudden perturbations while guaranteeing a pre-specified control objective (working in active or passive mode).

1. Introduction – motivation

The reception of vibrations is a special sense of touch, important for many insects and vertebrates as well. For examples, scorpions and spiders (see Fig. 1), and cats, mice or rats (see Fig. 2), have various sensilla or vibrissae to notice these vibrations.

We do not want to distinguish the different forms of sensilla, see [10] for a classification, but we state the following common property: 'the stimulus of this sense of touch is mechanical oscillation energy which is transmitted to the receptor cells in the case of direct contact with an oscillating object', [9]. Moreover, 'the cells for reception of vibrations adjust their sensitivity to a continuing excitation in such a way that despite this permanent excitation the whole system tends to the rest position', [7]. Hence, this biological paradigm offers a fundamental principle: **adaptation**.

Principally, the tenor of our investigations is from bionics: modeling live paradigms, exploit corresponding mathematical models in order to understand details of internal processes and, possibly, come to artificial prototypes (e.g., sensors in robotics).

2. First approach – simple model

As a first step, motivated by the last biological observation, we considered in [2,3] a simple sensory system. It was in form of a randomly moving rigid frame with an internal spring-mass-damper-system which is forced by an unknown time-dependent displacement, see Fig. 3. By the above mentioned adjustment of the receptor cells we were given the task to adaptively compensate (unknown) ground excitations. To do this we had to assume the existence of an internal control force $u(\cdot)$ acting

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doi:10.1016/j.cnsns.2010.04.049

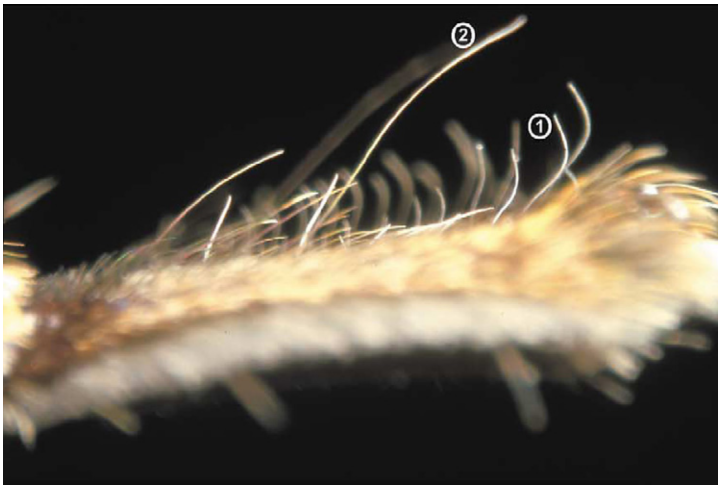

Fig. 1. A spider leg with sensilla, [1].

Fig. 2. Cat 'Alfred' with vibrissae.

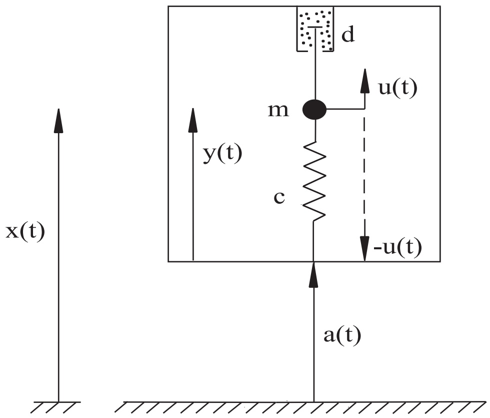

Fig. 3. A sensory system, [2].