Learning to bounce: First lessons from a bouncing robot

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1. Introduction

Ten years ago, Goldfield and colleagues [1] performed a longitudinal study in which eight 6-months old infants were strapped in a harness attached to a spring of known stiffness and damping, and were observed once each week for a period of several weeks, while they learned to bounce. At the onset of each experimental session, it was made sure that the soles of their feet could just touch the floor. Goldfield et al. found that in the course of learning to bounce, the infants' motor activity could be decomposed into an initial *assembly phase* in which kicking was irregular and variable in period, and a subsequent *tuning phase* characterized by bursts of more periodic kicking and long bouts of sustained bouncing, during which infants seemed to explore the mechanical properties of the mass-spring system. A third phase was initiated by a sudden doubling of the bout length, and was characterized by oscillations of the mass-spring system at its resonant frequency, a sensible rise of amplitude, and a decrease of the variability of the period of the oscillations.

2. Motivations

One of the main motivations for our own study resides in our interest for the mechanisms underlying the emergence of coordinated movement patterns, via the self-exploration of the sensorimotor space. It is our contention that self-exploration, while starting off with seemingly random, spontaneous movements, may converge to spatio-temporally organized motor activity as a result of the intrinsic dynamics of the neuro-musculo-skeletal system and its interaction with the environment. In fact, there is a growing body of evidence substantiating the claim that the control of movements resulting in particular (exploratory) actions is not determined by innate mechanisms alone, but rather, emerges from the dynamics of a sufficiently complex action system interacting with its surrounding environment [e.g. 2, 3].

3. Experiments and Results

In this study, we focused on emergent rhythmical activity, a salient characteristic of a developing motor system during the first year of life. Our experimental platform consisted of a small-sized humanoid robot with 12 mechanical degrees of freedom. The robot was suspended, through a leather harness, to two springs. The neural control architecture took the form of a connected set of six *Matsuoka-type* neural oscillators. With a primary focus on the *tuning* phase, four experiments were performed. In the first two experiments the robot was let oscillate freely in space. These experiments served to assess the characteristics of the mass-spring system. In the other two experiments the robot could touch the ground (as in Goldfield's study). One result of our study was that in the case of a freely oscillating robot, parameter changes could lead to at least three oscillatory modes. Another result was that sensory feedback induced a reduction of movement variability, an increase of bouncing amplitude, and eventually led to stability. A similar finding, in the case of biped walking, was reported by Taga [4] who stated that through a recurrent interaction of sensory information and movement generation, the instability of the human body was stabilized as a limit cycle.

References

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