Abstract

Rhythmic motions, regular or irregular, are an integral part of motor behavior both in health and in disease. Better understanding of its neural control mechanisms helps in developing methods for controlling the progression of diseases manifesting as rhythmic motions. I studied two specific aspects of rhythmic motions: bilateral coordination of hand tremors in human subjects and modular control of locomotion in invertebrates.

Many types of tremors, including the physiological tremor (PT) and the essential tremor (ET) occur in limbs on both the sides of the body, with similar fundamental frequency of the oscillation. This raises the possibility that the contralateral tremors may have a common source or are otherwise coupled. However, while significant contralateral interaction is seen in these two types of tremors, only limited evidence of bilateral coherence has been shown in the previous literature. Therefore, in my study I explored the existence of a weak coupling between the left and right oscillators the may lead to intermittent bilateral coherence. I measured triaxial acceleration of the two hands and systematically assessed their bilateral coherence, using both stationary and non-stationary (wavelet-based) analyses methods. Measuring all three axes allowed examination of a more complete set of kinematic variables than in most previous studies. The majority of both PT and ET subjects displayed significant bilateral coherence in the frequency range 1-10 Hz. In both the cases short epochs of several seconds with strong coherence were separated by intervals of insignificant coherence. To probe the contribution of the cardiac impulse that is common to both the hands, I measured the acceleration of the chest wall simultaneously with that of the two hands and estimated their partial coherence subject to the chest motion. Results indicate that in PT, bilateral coherence at the main tremor frequency (i.e. in the range 6-12 Hz) arises from a joint coupling of the hand oscillations to ballistocardiac forcing.

In the second part of my work I studied modular control of locomotion in the invertebrate model organisms for neuromotor control, the fruit fly *Drosophila melanogaster*. Modular motor control implies that a particular group of muscles is simultaneously activated to generate a specific motor pattern. The aim was to investigate if the various flight maneuvers arise from the activation of a small number of independent neuromuscular control modes. I measured the wing motion of tethered flying fruit flies for long uninterrupted flight

durations (~60 seconds) with a high-speed computer vision system. With a novel method based on the least-dependent component analysis I decomposed the joint motion pattern of both wings into components that have the minimal mutual information (a measure of statistical dependence). Using this method I identified four types of kinematic patterns that can be activated mutually independently, and occur both in isolation and in linear superposition. Three of the identified elementary patterns can be associated with body yaw control, body pitch control, and control of flight power. The fourth kinematic pattern consists of an alteration of stroke amplitude with a period of 2 wingbeat cycles, extending for dozens of cycles. This kinematic pattern is novel and interesting, as its features indicate the activity of a control system that operates at the times scale of a single cycle; Hence, I studied it in some details.

In conclusion, my study has put forth two major findings regarding the neuromuscular control of rhythmic motor activities: i. The hand tremor in PT and ET are intermittently synchronized. Such transient but recurring synchrony indicate a weak coupling between the tremors of the two hands. Although the coherence at the main tremor frequency can be explained by the simultaneous cardioballistic forcing, the origin of the low frequency bilateral coherence (i.e. 1-6Hz) needs to be explored. ii. Complex kinematic patterns during insect flight can be generated from linear combinations of elementary kinematic patterns that are controlled mutually independently. This provides strong evidence for the presence of modular motor control of rhythmic motion in invertebrates.