KINETICS OF RAT LOCOMOTION NEGOTIATING ACTIVE PERTUBATIONS

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The understanding of the organization and function of spinal motor systems is one mayor topic in animal locomotion. Although spinal sensorimotor systems were studied in detail, we still know little about the descending systems in the brainstem and how they interact with spinal circuits [1,2]. For example, how do these systems ensure stable locomotion across rough terrain? Or how do descending circuits from the brainstem interact with spinal sensorimotor systems to produce flexible motor function? Tackling such questions requires a multidisciplinary effort. In the international project Neuronex (https://c3ns.org), we combine behavioral, neurophysiological, computational, and robotic experiments to understand how mechanical scale and task demands determine the function of low-level control centers in the spinal cord and their interactions with high level control centers in the brainstem in small mammals.

The development of synthetic neuronal systems, which is one of the main goals of our project, will help to link all these scientific fields. We already have used simplified synthetic neuronal systems to test and develop cutting-edge hypotheses regarding motor control [3]. We expect that more advanced versions of them will be implemented as bio-inspired control system for robots and wearable devices (e.g., exoskeleton).

More sophisticated synthetic neuronal systems need to mimic the interactions between spinal-reflex control and higher locomotor centers. Small mammals like the rat are a good animal model to infer such interactions during posture and quadrupedal locomotion. Like for any dynamical system, their control strategies can be characterized by analyzing how they respond to external perturbations. We believe that active perturbations might be adequate to address the interplay between lower and higher locomotor centers. They can help to ask, for example, if there a threshold exists, at which spinal-reflex loop need to be helped by higher locomotion centers. Following this idea, a novel three-degrees of freedom platform, called "the shaker" was developed [4]. The shaker can generate single or combined horizontal, vertical, and tilting perturbations with a payload up to 1 kg. It can produce horizontal and vertical perturbations with amplitudes up to 1 cm at oscillation frequencies up to 10 Hz. The tilting motions were constrained to 15°/s. In addition, the shaker can measure single ground reaction forces (GRF) using up to four custom-build force plates mounted on the platform (see Fig. 1 A). In the conference, we will inform about the kinetic results of the world-wide first studies on rat actively perturbed locomotion. In those experiments, which were approved by the Committee for Animal Research of the State of Thuringia, Germany (registry number: 02-060/16), rats moved across a 2.3 m walking track, constructed around the shaker, at their preferred speeds. During active perturbations (horizontal and vertical), we recorded three-dimensional bones kinematics, single leg GRF, and electromyography of selected muscles of the hind limbs. We expect that by measuring motor responses to a range of perturbations, we can define the functional mapping between deviations in limb state, center of mass dynamics, and muscle activations.

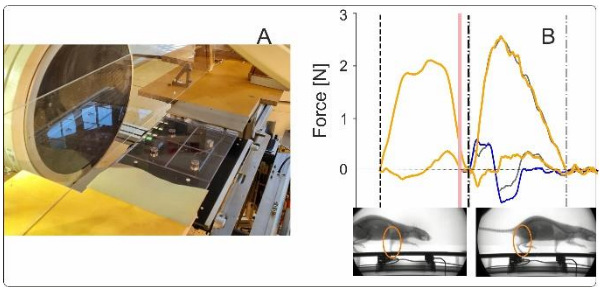

Figure 1: Analyzing rat active perturbed locomotion. A) Experimental setup combining biplanar X-ray, and an active platform ("shaker") with force measure. B) ground reaction forces before (right forelimb) and during a horizontal perturbation (right hindlimb). The platform was shifted 10 mm in 0.05 s towards cranial. Grey lines represent the forces measured by the plates, blue lines the forces produced by the dynamics of the motion, and orange the forces exerted by the rat.

References

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