Rewiring the nervous system, without wires

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When telecom cables break in middle of the ocean, miles below the surface, a robot finds the broken ends, hoists them up, and a skilled "jointer" splices and reattaches the glass fibers. The repaired cable is then lowered back to the seabed. Unfortunately, when the communication cables of the human body break due to injury or disease, there is no jointer coming to the rescue. Instead, tissue inflammation and chemical release make rejoining near impossible (although an active area of research). We have focused on bypassing the site of injury by wirelessly transmitting neural code from the brain down to spared circuits of the spinal cord, in the hope of reanimating the lower limbs and restoring locomotion.

In this talk, I will introduce a neuroprosthetic platform capable of spatially-selective electrical spinal cord stimulation that is orchestrated by subject's intentions decoded from motor cortex population activity. We have engineered a compact, lightweight, high data rate wireless neurosensor capable of recording the full spectrum of electrophysiological signals from the cortex of mobile subjects. We then applied this neurotechnology to envision a brain-spinal interface, readdressing the long-sought goal of rewiring the nervous system after injury. Using this unconventional platform, we have mapped adjustments in electrical spinal cord neuromodulation to specific changes in leg kinematics, muscle activity, and neural states of the motor cortex during continuous locomotion in non-human primates. The entire platform was implemented within a wireless framework, it required no percutaneous cables for operation, and it enabled free ambulation by the animal subject. Developments in wireless technologies establish the settings for the translational design of neuromodulation therapies offering new directions in the treatment of neuromotor disease and disorder.

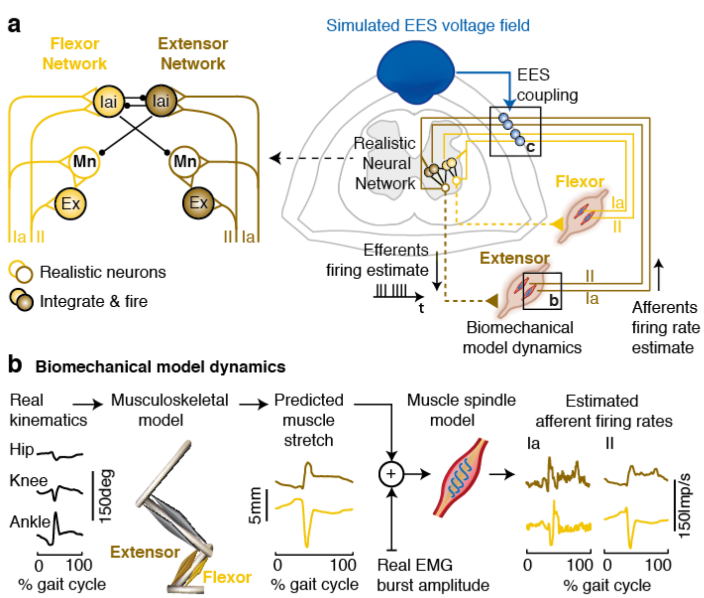

Fig. 1: Model of spinal sensorimotor networks: (a) spinal cord agonist-antagonist spindle reflexes are modeled as a cross-inhibiting spiking network; (b) the dynamic firing rate of afferents is simulated by solving the inverse kinematics of healthy animals during bipedal stepping via a realistic musculoskeletal model; (c) number of fibers stimulated by EES is computed via a validated finite element model. (d) simulations of the efferent output produced by EES stimulation at the S1 segment of increasing intensity.