A New Approach to Neurological Signal Decoding: Algorithm and System (Case 1426)

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Technology description

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Brief Description:

Primates are particularly adept at directing their hand to a moving and unpredictable visual target. Visually guided movement is fundamental to many behaviors, but the nature of cortical coding of this behavior is not understood. The process of using vision for manual tracking engages a collection of cortical areas in the brain, and primary motor cortex (MI) is one such important active area indicated near the final stages of hand motion control. The firing rate of single MI neurons can provide movement information such as direction, velocity, speed, position, acceleration and force. However, understanding what and how information is coded in MI has been difficult to determine using current approaches.

A major difficulty in understanding hand motion or movement coding in MI is relating behavior to neural activity. Prior studies treat motor variables as averaged and static quantities, rather than as appropriate time-varying signals continuously guided directly by vision. The use of static quantities or tasks present numerous difficulties in addressing the combined spatial and temporal aspects encoded by MI neurons. These problems include: 1) limited space sampled for each variable, e.g., target direction; 2) limited control over variables, i.e., how a hand moves between targets is a function of an individual’s strategy and not experimental design, and thus various statistical dependencies can appear in hand motion, e.g., position, velocity, speed and initiation that are often correlated with neuronal firing rate; 3) highly parametric models of firing are assumed, thereby removing more complex structure potentially present in a neuron’s firing pattern; 4) the introduction of non-stationarities in which neural and behavioral signals co-vary in association with various trial-based epochs making it difficult/incorrect to evaluate motion quantitatively; and 5) difficulty in comparing detailed features of neural encoding because neurons are recorded serially under behavior, neural or state conditions, which may vary for each neuron. As such, current methods are significantly insufficient in their ability to further our understanding of the neuronal coding of movement. For all of the above reasons, a more accurate and appropriate method is needed to advance the field.

The invention is a new approach to characterize MI encoding of hand motion and is comprised of a novel system that combines a mathematical algorithm, electromechanical (physical) components, and a biological system. The innovative system uses neurological control signals to control a device. However, this invention may be used to sense biological electrical activity from other cell types – not only neural. A systems analysis framework is used to describe (quantify and directly compare) the position and velocity information available in MI, such that hand motion is viewed as a stimulus and neural activity as the system’s response. A continuous tracking task (CTT) is utilized to apply this approach. A multielectrode array acquires the activity of multiple MI neurons simultaneously during a hand motion or behavior. In this way, hand motion is effectively controlled at all times thus reducing or removing statistical dependencies among variables. This inventive method can potentially return an accurate description of the spatial tuning of MI neurons and can reveal how this tuning evolves over time. Spatiotemporal tuning of velocity and position for MI neurons are described, and information coded within single neurons are compared across the cell population. Furthermore, the approach permits a direct test for the existence of hand trajectory information using signal reconstruction methods. This new method demonstrates that MI neurons contain sufficient position and velocity information to reconstruct any new hand trajectory/motion based on information available from the firing of a small number of nearby MI neurons.
In summary, this system is directed toward a plurality of neurons over time. Physical embodiments use a neurological control signal to control a device, which is comprised of a sensor to sense electrical activity of many neurons over time, a vector generator to generate a neural control vector, a control filter, a controller to apply the neural control vector to the control filter to produce a control variable, and an output device controlled by the control variable. Electrical activity may be from many sources: neuronal action/threshold potentials; subdural electrocortigram/electroencephalogram signals; and motor control commands. Recording/sensing of electrical activity may be via implanted electrodes in the central nervous system or an array of electrical sensing elements. The motor output device can be a natural limb, prosthetic, a part of the human body – limb or other –, a computer input device, a robotic arm, wheelchair, voice synthesizer, microchip, among many others.

Application area

use in neuroprosthetic systems, other implantable medical devices, or wherever brain- and/or body-machine interfaces are required for treating neurological, psychological or other medical impairments, diseases, or conditions; as a scientific R&D research tool for use in experiments to advance the fields of mathematics, biomechanics, biomedical engineering, neuroscience, psychiatry, behavioral sciences, neurology, among others.

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