Gain Modulated Populations of Neurons for Three Dimensional Frames of Reference Transformations

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When performing visually-guided movements, the brain faces the problem of transferring information across different frames of reference. Visual information gathered in a retina-based frame of reference (FR) must, for instance be first transferred in head-centered FR, then in body-centered, and finally in hand-centered FR.

During past decades, neurophysiological experiments have shown that a computational paradigm, namely *population vector coding*, seems to be shared by several areas of the nervous system, including proprioceptive receptors, the motor cortex, and parts of the sensorimotor pathway, such as the posterior parietal cortex. It appears, thus, to be a possible common principle of brain organization, that allows different neural populations to store and share multimodal information in different frames of references in the purpose of accomplishing tasks.

The investigations on how population vector coding can be used as mechanism to accomplish vectorial transformations have led us to present a demonstration of how populations of neurons can proceed arbitrary 3-dimensional (3D) rotations and translations. Our model is based on a continuous and uniform attractor network architecture where each neuron participating in the vector code is characterized by three major properties, consistent with neurophysiological data, namely: 1) a *preferred direction*, i.e. the direction for which its firing rate is maximal, 2) a *cosine tuning curve*, i.e. the neuron activation is proportional to the dot product between the direction coded by the population and its preferred direction; 3) *gain modulation* i.e. the neural activity can be modulated multiplicatively by a constant external input or background synaptic activity. The first two properties are used to encode and decode a vector in and from a population, while the third one is the result of the recurrent dynamics of our network. Hence, we are able, from neurons that linearly integrate their inputs, to produce gain fields, neural basis of nonlinear transformations. In addition, linear transformations, as vector summation are performed in the synaptic weights between populations. From these principles and properties, we successfully accomplished 3D frame of reference transformations, being the result of the serialization of elementary operations, that can be justified by the gradient hypothesis for sensorimotor transformations along the neocortex.