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THE VESTIBULO-OCULAR REFLEX IN RABBIT, AS INTERPRETED USING THE MOORE-PENROSE GENERALIZED INVERSE TRANSFORMATION OF INTRINSIC COORDINATES. J.I. Simpson and A. Pellionisz, Dept. Physiol. Biophys. N.Y.U. Med. Ctr., New York 10016.

The vestibulo-ocular reflex (VOR) provides a specific model for a quantitative application of the tensorial treatment of sensorimotor coordination introduced by Pellionisz & Llinas (1979,1980). Their theoretical approach, treating vectorial expressions in intrinsic reference frames, raised two key issues: the non-orthogonality and the potential overcompleteness of these reference frames. These issues can be presented by considering the kinematic analysis of eye movements, although the broader focus is the interpretation of the sequential transformations in the VOR, where the frames may be overcomplete. Eye movement is typically treated as a 3 degree of freedom rigid body rotation caused by the action of 6 muscles, each with its own rotation axis. The excess of the number of muscle rotation axes over the number of degrees of freedom means that, unless constraints are introduced, a particular eyeball angular velocity cannot be resolved into a unique set of contravariant component rotations in the 6 dimensional muscle reference frame. Rather, an infinity of such component sets exists. For the eyeball, this problem can be "resolved" by reducing the dimensionality from 6 to 3 by muscle pairing. This approximation permits a matrix description of the input-output transform, but without interpretation of the network transformations in between. Moreover, such reduction may not be applicable to other motor systems, e.g. the neck. Other approaches exist, but they all involve some approximation. One alternative approach uses the Moore-Penrose generalized inverse, as proposed by Pellionisz (1983). This approximation preserves the eigenvectors of a matrix. From measurements of the physical arrangement of the rabbit's extraocular muscles, the Moore-Penrose generalized inverse has been calculated and is interpreted as the oculomotor metric tensor in the VOR transform. Some advantages of this approach are that it is general, the identity of the individual muscles is preserved, and the interim neuronal transformations can be represented. Keeping the intrinsic coordinates distinguishable is also likely to prove important in extending the analysis of eye movements from kinematics to dynamics, and beyond, to the functional geometry of neuronal control. Supported by NIH grant NS13742 from NINCDS.

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