WHY IS IT EASY TO CONTROL YOUR ARMS?

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How can our nervous systems control all the variables needed to guide our arms? How can we represent the abstract pattern of an action such as handwriting so that it may be realized in any of an infinity of variants--large, small, horizontal, vertical, with the hand weighted, or even by holding the pencil stationary and moving the paper? Most researchers who try to represent movements of artificial arms by means of computer programs have chosen, in the interest of supposed computational simplicity, to use the smallest number of "degrees of freedom", or independent joint movements that will allow desired hand movements. I will discuss the opposite idea: namely, the idea that a large number of "redundant" degrees of freedom, when used in the style that I will discuss, can simplify the control task, in that, if there are enough ways of moving, a recipe involving just a few of them can usually be found that will approximate any desired movement. In particular, the presence of "redundant" degrees of freedom allows us to rely more on ballistic (free-swinging) movements than is generally done in research on artificial arms, so that physics, rather than computation, accounts for much of the trajectory. Computations are required to set up the constraints defining and initializing a low-degree-of-freedom "virtual arm" in such a way that a satisfactory ballistic movement exists. Thus, a complicated physical arm behaves like a family of easily controlled virtual arms.

Among the points to be discussed: Using momentum saves energy, and it simplifies control. Movements may be controlled by sending new parameters to systems that control the muscles, rather than by controlling the muscles directly. The principal task in tracking a moving object, rather than being to minimize instantaneous errors, may be to synchronize an internal pattern generator to the movement. The present style of control identifies similar movements as cousins, rather than regarding them as unrelated computations. The same overt muscle movement can be more or less difficult, depending upon the higher up patterns in this hierarchy from which it is derived.

(See Greene, P.H. (1972), Problems of organization of motor systems, in Rosen, R. and Snell, F.M., eds., Progress in Theoretical Biology, Vol. 2, New York: Academic Press and Greene (1982), Why is it easy to control your arms? Journal of Motor Control, to appear.)