Functional Organisation in the Cerebellum

L.N.Kalia*
Neural Systems Engineering, Dept. of Electrical Engineering,
Imperial College, Exhibition Road, London SW7 2BT, U.K.

The structure of the cerebellum is examined and the emergent functional organisation deduced. This yields the observation that the cerebellum exhibits two forms of modularity of importance in artificial neural network models. Emphasis is placed on the definition of the individual cerebellar module, on the inhibitory mechanisms which lead to efficient modular action, and on how parallel fibres serve to link together, or coordinate, the activity of different modules.

It is proposed here that the cerebellar module should be defined as a *composite* of the two organisational schemes (vertical and parasagittal) which *coexist* in the cerebellum. In this way the cerebellar module is seen as a complex adaptive control system in its own right displaying feedback and feedforward characteristics.

Roles are proposed for the inhibitory interneurons: the Golgi cell feedback loop is seen as performing thresholding, for the purpose of detecting time-locked stimuli, and also, as a way of imbuing temporal sensitivity to the representation surface provided by the granule cells. Laterality in basket cell connectivity is interpreted as a means of performing competition between parallel fibre beams. Three possible functional roles for the basket cell circuit are that it serves (i) as part of an attention mechanism acting on the cerebellar cortical surface; (ii) as a target-setting mechanism and (iii) as a means of making the Purkinje cells sensitive to the normalised form of the spatial pattern of the parallel fibre wavefront. From the localised nature of stellate cell connectivity it is proposed that they are responsible for the functional parcellation of the Purkinje cell dendritic tree into competing blocks.

The hypothesis is put forward that cerebellar control of coordination arises from the coordination of activity in its constituent modules which, in turn, is brought about by the parallel fibres which supply information to many modules simultaneously *and* provide a given module with contextual information regarding the activity in other modules. In this way the individual modules are able to act in a *learned* synergy. From an evolutionary perspective, the parallel fibre projection can lead to the augmentation of existing modules as new modules are incorporated into the cerebellar structure.

The interplay between feedforward and feedback schemes in defining the cerebellar module and the concept of coordinated multi-modular action may be a neurobiological concept relevant to problems in control engineering. Artificial neural networks are an ideal paradigm for investigating the interplay between structure and function, as described in this paper, embodying as they do a structural approach to computation.

References

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