Abstract

Investigating the Storage Capacity of a Network of Cell Assemblies
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Cell assemblies are co-operating groups of neurons believed to exist in the brain. Their existance was proposed by the neuropsychologist D.O. Hebb who also formulated a mechanism by which they could form, now known as Hebbian learning. Evidence for the existence of Hebbian learning and cell assemblies in the brain is accumulating as investigation tools improve. Researchers have also simulated cell assemblies as neural networks in computers.

This thesis describes simulations of networks of cell assemblies. The feasibility of simulated cell assemblies that possess all the predicted properties of biological cell assemblies is established. Cell assemblies can be coupled together with weighted connections to form hierarchies in which a group of basic assemblies, termed *primitives* are connected in such a way that they form a *compound* cell assembly. The component assemblies of these hierarchies can be *ignited* independently, *i.e.* they are activated due to signals being passed entirely within the network, but if a sufficient number of them are activated, they co-operate to ignite the remaining primitives in the compound assembly.

Various experiments are described in which networks of simulated cell assemblies are subject to external *activation* involving cells in those assemblies being stimulated artificially to a high level. These cells then *fire*, *i.e.* produce a spike of activity analogous to the spiking of biological neurons, and in this way pass their activity to other cells. Connections are established, by learning in some experiments and set artificially in others, between cells within primitives and in different ones, and these connections allow activity to pass from one primitive to another. In this way, activating one or more primitives may cause others to ignite. Experiments are described in which spontaneous activation of cells aids recruitment of uncommitted cells to a neighbouring assembly. The strong relationship between cell assemblies and Hopfield nets is described.

A network of simulated cells can support different numbers of assemblies depending on the complexity of those assemblies. Assemblies are classified in terms of how many primitives are present in each compound assembly and the minimum number needed to complete it. A 2-3 assembly contains 3 primitives, any 2 of which will complete it. A network of N cells can hold on the order of N 2-3 assemblies, and an architecture is proposed that contains $O(N^2)$ 3-4 assemblies. Experiments are described that show the number of connections emanating from each cell must be scaled up linearly as the number of primitives in any network increases in order to maintain the same mean number of connections between each primitive. Restricting each cell to a maximum number of connections leads to severe loss of performance as the size of the network increases. It is shown that the architecture can be duplicated with Hopfield nets, but that there are severe restrictions on the carrying capacity of either a hierarchy of cell assemblies or a Hopfield net storing 3-4 patterns, and that the promise of N^2 patterns is largely illusory. When the number of connections from each cell is fixed as the number of primitives is increased, only $O(N)$ cell assemblies can be stored.