The Brain and Computation

The brain, consisting of $O(10^{10})$ neurons, is basically a memory system which functions by associating memory traces to input cues and by generalizing among the memory traces in response to such input cues. It is probably a layered and parallel structure, so that the key recall process (with generalizations) is repeated at many different levels and in a highly multiplexed way.

The basic brain operations are slow ($10^{-3}$ sec compared to $10^{-10}$ sec (the best current silicon), but they are enormously more efficient ($10^{-16}$ joules/op sec compared to $10^{-6}$ joules/op sec). Assuming that this synapse is the basic switching element, these are of the order $10^{14}$ synapses/brain, say $10^{14} \cdot 10^{3}$ ops/sec. Then the energy requirement of a brain is $O(1)$ (assuming that every synapse is continuously operating).

The von Neumann/Turing notion that computation consists of moving bits to and from memory to an arithmetic unit for a basic operation is an essentially irrelevant mathematical construct in this context. Layers and highly parallel memory systems at work in the brain are what results in its rapid and robust cognitive functionality.

Making mental models is an oversimplification of thought in conventional terms. The brain processes its data in extraordinary ways (edge info, motion info, shape... for vision) to create its “signal features” for storage. The brain probably does not make models of the sort found in engineering experience, e.g. a photo archive. Images (for vision), scents (for smell), sounds (for hearing) … are processed and stored as memory traces in ways which are now only starting to become known. “The feature vectors” of this brain modeling (storing) are likely very different from those of our technologic experience. They are probably chosen by evolutionary forces to improve and refine this capacity and efficiency of neural systems as controllers.

To understand the cognitive abilities of brain and to carry over this understanding to contemporary technology, will require deeper studies of the neuronal “feature” processing, its “data types” and its storage and “association” schema. It will also require the development of the ability to create and package enormous numbers of extraordinary efficient switches. Of course, the possibility of trade-offs against the speed of silicon needs bearing in mind.

As the subtleties (peculiarities) of the brain’s functionality are uncovered, the peculiarities of the “biologically evolved” processing techniques will be subjected to the usual kinds of engineering prejudice (e.g. digital vs. analog). Judicious choices must be made between concepts and practices.