SECTION 7

Accessing Memory

THE PROBLEM

The fundamental problem of memory, of any memory system, is that an extremely large number of different things, varying greatly, must be stored and be able to be accessed readily, quickly, and at very low cost in terms of access time and in terms of the amount of access mechanism required.

While this problem has existed for a long time in various practical examples of file systems and libraries the fundamental problem was easily resolved in those cases by virtue of each memory object having its own specific, addressable storage location. That is, in such a system each object is stored in its own specific physical location and identification of that location and going to it are systematic not random. With the advent of digital computers the same solution of addressable storage locations was readily applied to the computers' digital memories.

But, with the advent of the World Wide Web [WWW] of the internet that solution would not work. The extremely large number of objects [instances of information] to be stored and yet be readily accessed is in the WWW not subject to specific systematic addresses; rather, the objects are all effectively stored randomly. That requires a whole new solution to the memory problem.

That same memory problem that we became aware of in the WWW appears again in the issue of human memory and the functioning of the brain. The brain, whether human or animal, stores an immense number of retrievable objects but they are not stored in systematically addressable fashion but, rather, not addressably which is effectively randomly. Every memory is stored distributed over the entire brain region involved.

The obvious initial approach to WWW / brain memory access and retrieval was to "plow through" from the beginning. One has an identification [ID] of the object desired and checks the first stored object to see if the ID matches. If matched the retrieval is successfully done. If it is not matched the search goes to the next stored object *ad infinitum*.

The "check" requires retrieving the object's ID and comparing it to the search ID. A digital computer can do that quite rapidly by: [a] retrieve the object's ID; [b] subtract the search ID from it; [c] if the result is zero deliver the object or [d] if the result is not zero proceed to the next object. But even the most rapid computer can take days, weeks, years to search through billions of objects and both the WWW and the brain store many billions of objects.

After extensive research and experimentation the solution to the problem for the WWW was developed and employed. That solution is called "indexing". The search does not involve directly retrieving each object to test for a match. Rather, the search is of a "tree" consisting of a master list, its sub-lists, their sub-sub-lists, and so on.

Suppose as an example that each list has 100 items, 100 entries. Suppose that there is only the master list and its sub-lists and that the object sought is the 55^{th} entry in the 70^{th} sub-list. Then:

[a] In the "plow through" method one must scan, searching for an ID match up to $69 \times 100 + 55 = 6{,}955$ entries.

[b] By the index method one must scan up to $70 + 55 = 125$ entries.

That reduction in the number of entries to be scanned and checked is a corresponding reduction in the amount of time the search to retrieve a particular memory can take. Furthermore, increasing the depth of sub-listing from just the master and one sub to the master and a number of levels of progressively deeper subs magnifies the speed improvement tremendously.

That direct WWW indexing method of memory structure and retrieval cannot be employed in a brain. A brain is not susceptible to linear scanning of lists. But as will be seen, the brain does have an efficient indexing system that includes automatic updating of the indexes and more efficient search of the indexes than linear scanning. The brain's system is addressed in Section 8.

MULTIPLE SENSORS

The discussion to this point describes the activity for a single unitary memory; but, the principal input to memory is from the senses: sight, sound, smell, taste, touch, body functions and body position and intangibles such as thoughts and emotions. Each has its own particular region of the brain in the neurons of which the inputs from its sensory sources are stored. In addition there are purely internal brain memory regions dealing with language, emotions, etc.

In each sensor's particular region of the brain, having on the order of 10^8 neurons per equation 6-1, memories are not stored in specific locations. Rather every memory is stored in the total collective 10^8 neurons. Of that total each memory is represented by the firing of its own particular subset of the total available neurons. The firing of that subset represents a set of universals, the particular set of universals corresponding to the neurons fired, which collectively define and <u>are</u> the thing remembered.

Per equation 6-2 each such memory object is one neural pattern out of the innumerable myriads of possible neural patterns in each memory region.

The stored results, memory objects, are like “video” recordings of the sensory inputs. They store successive “frames” or “snapshots” of the action. Since they arrive from the sensor in time sequence the successive “frames” are stored, in successive neural firings, generally in time sequence – like a “video”.

The firing of the particular set of neurons that are the memory object causes the thresholds of those specific neurons to be decreased making subsequent firings of those neurons more likely. The particular set of neurons having such specifically decreased thresholds are the recorded memory object.

Memory objects from sensors are not distinguishable from thoughts except that some or all of the inputs to thoughts derive from other thoughts which is not the case for sensory inputs.

The act of remembering an object, is “re-playing” [re-thinking] its “video” in memory. The pattern of neural firings that were the remembering of a particular input at the time of its being sensed is reactivated and reproduces the original act of remembering. But, then, how is that memorizing and remembering accomplished ? How are the separate “videos” for each of the senses, residing in their own region of the brain, reassembled into an overall experience ?

Because a total memory is stored in pieces in a variety of unrelated neural locations each for a specific sense there must be a means for keeping track of them all and reassembling them, in effect undoing the unavoidable breaking apart of a real world event into separate specific sense events.

Another separate part of the brain must have the function of recording the identification [ID] and the location of each memory input to each sensor region of the brain. Experiments have shown that that function is performed by the brain’s hippocampus [hereafter called “Memory Management System” or MMS].

The input arriving at each of the brain’s particular sensor or memory regions for each type of sensor or memory is further transmitted as just the ID of that input to the MMS along with the location of the access points to the start of its “video”. The MMS does not record all of an input; rather what is retained in the MMS is the ID in the form of enough of the “starting frame” as to constitute a fairly unique identification of that input, and how to access that “starting frame’s” “starting location”, for accessing the entire input “video” beginning there.

But how ? What mechanism can accomplish all of that ?

THE MEMORY MANAGEMENT SYSTEM

Specific inputs are not stored in specific locations in their sensors’ brain region. Each “frame” of input uses the entire region, non-firing neurons [0’s] being just as significant as firing neurons [1’s]. It is necessary that the neural interconnections are such that a statistically valid sample of the overall sensor region array of neurons is connected to a corresponding section of the Memory Management System [MMS] dedicated to that sensor so that the statistically valid sample is recorded in the MMS for that sensor upon the selected firing of that sensor's brain region neurons.

It is likewise necessary that the neural interconnections are such that each of the neurons in the MMS for each sensor region is connected to and can contribute to the causing of the firing of the corresponding neuron in the original statistically valid sample in the sensor' brain region.

Via that statistically valid sampling the MMS has a unique ID of the memory input involved and in the event of that ID being activated the MMS causes the sample neurons in the sensor brain region of the sample to fire which firing as a statistically valid sample of the original input is "remembering" the memory [not as sharply defined as the original, but that is the way of memory].

Subsequently if that ID and "starting location" are accessed from time to time then the ID and "starting location" are then reinforced; and if that ID and "starting location" are not accessed then that record gradually decays to non-existing, having been overwritten by numerous other more recent such records accessed more frequently.

If in the MMS a particular sensor region's memory, for example that for smell, were activated alone then merely the smells of that memory would be remembered.

If in the MMS all of its various sensor regions for statistically valid samples of the particular memory are simultaneously activated then the entire specific memory with all of its sensor inputs is activated and "remembered". But, how is an MMS sensor region sample selected ? Further, how are a subset of MMS sensor regions samples simultaneously activated ?

Access to memories is a function of the brain's Operating System.
That brings us to the Executive System and control of the MMS.