

Mind: Probability Functions on Matter

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Abstract A recent theory for concept storage [1] claims that each concept (or memory) such as for example a visual image of grandma's face is coded in a neuron or cluster of neurons in the cerebral cortex. One of the main drawbacks of this theory is that it limits the number of storable concepts by the number of neurons. We propose an entirely different mechanism for storing concepts in the brain. Rather than dedicating a neuron or neuronal cluster to a concept we suggest that the brain stores the concept as a probability function on the involved neuronal clusters. Infinite versions of a concept can now be represented by different probability functions on the same neuronal clusters since the space of probability functions is much richer than the space of neuronal clusters itself. Further implications of this framework for storing concepts are discussed.

Keywords Neuronal clusters, Probability functions, Dynamical systems, Invariant measures

1. Introduction

We present a theoretical framework that reflects the notion of concept and memory (mind) as an infinite collection of weighted patterns (probability functions) on neuronal clusters (matter). Let us consider an interconnected network of clusters that is activated when an image or concept is in effect. Dynamically, trains of electrical spikes are racing through the connected network. If the volume of all the clusters were the same and the firing rates in all clusters were the same also, we would have uniform activation on all the clusters. However, this is rarely the case since clusters in a connected network may have very different firing rates [7] and different volumes, resulting in different levels of activation on the clusters of the same interconnected network. This is a result of the nature of the different synaptic connections that control the rates of the spike trains entering each cluster.

The firing pattern in the connected clusters persist as long as a concept is maintained. During this time a state of dynamic stability is achieved. We suggest that there is an underlying system such as a nonlinear deterministic map that reflects the electrical dynamics. In theory such maps can be determined if the interconnections between clusters and the volume of each cluster is known. Although stable, the system is dynamic and may appear random. Such behavior is captured by the mathematical notion of an invariant probability function [8, Chapter 9] on the clusters. Invariant probability functions in the context of brain dynamics have been studied in [3-6].

Let us now consider a basic concept such as grandma. Let D denote the interconnected collection of disjoint neuronal clusters activated by grandma, and let P_D be the collection of all probability functions on D . It is reasonable to assume that for each concept related to grandma each cluster in D activates one or more other clusters in D . It follows that there exists a map β from D into D describing the interconnections between the clusters of D . The Perron-Frobenius Theory [8] guarantees the existence of an invariant probability function f^* associated with the specific concept related to grandma.

A number of interesting properties follow:

- 1) f^* is stable under small perturbations of β . That is, concepts "close" to grandma result in functions "close" to f^* . For example, grandma smiling is close to the general concept of grandma.
- 2) Suppose f^* is in P_D and g^* is in P_G , where f^* and g^* correspond to two different concepts. (D and G can overlap.) Then for any number α , $0 \leq \alpha \leq 1$, the convex combination $h = \alpha f^* + (1-\alpha) g^*$ is again a probability function, corresponding to a combined concept. The degree of combination is captured by the parameter α . In [1] the authors superimposed images of Josh Brolin and Marilyn Monroe on a computer screen then altered the balance between them by having patients emphasize one or the other of the celebrities in their thoughts. In our model, the parameter α is shifted between 0 and 1. Furthermore, the convex combination probability function corresponds to a random map $\{\beta_D, \beta_G; p\}$ [9], whose dynamics switch between β_D and β_G , with probability p of using β_D (the image of Brolin) at any given moment and probability $1 - p$ of using β_G (image of Marilyn Monroe).

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Published online at <http://journal.sapub.org/ijbcs>

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- 3) In [1] the authors note that the brain "may not have enough neurons to represent all possible concepts and their variations." In our model the domain (clusters of neurons) forms merely the base on which the probability functions reside, and these probability functions are infinite in number. For example, if there are 9 clusters involved in storing a concept, then *any* 9 numbers (normalized to add up to 1) define a probability function.

2. Experimental Evidence

It has been experimentally verified in [7] that seeing a face and thinking about the face result in the same areas of the brain being activated. In mathematical terms this property is referred to as 'folding' and plays an important role in establishing deterministic chaos [6]. The visual stimuli for the face and the thought process for the face stem from different areas of the brain yet activate the same domain interconnected clusters D .

It is unlikely that completely different stimuli will trigger the same temporal sequence of spike trains on exactly the same set of clusters. We, therefore, suggest that this implies the actual sequence of cluster activations are not relevant. What is important is merely the intensity of activation of the clusters. This suggests that it is a weighting of activity (probability function) on D that characterizes the face.

3. Proposed Experiment

Functional brain images can locate the clusters involved in a given concept. To "weigh" the activity in these clusters requires a new experiment. This would necessitate determining the firing rate r into each cluster [7] and calculating the size (volume) V of each cluster. A simple measure of activity in a cluster might be rV . Determining this measure for each cluster in the network, then normalizing, yields the probability function corresponding to the concept.

4. Conclusions

The main idea of this note is that a concept or a memory is stored as a probability function on a collection of neuronal clusters and that the brain is able to store and recognize probability functions. This approach allows us to quantify variations of concepts in terms of perturbations of a starting probability function. Also, combining concepts has a mathematical counterpart in combinations of probability functions. Experimental evidence is presented in support of this proposal and a future experiment suggested.

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