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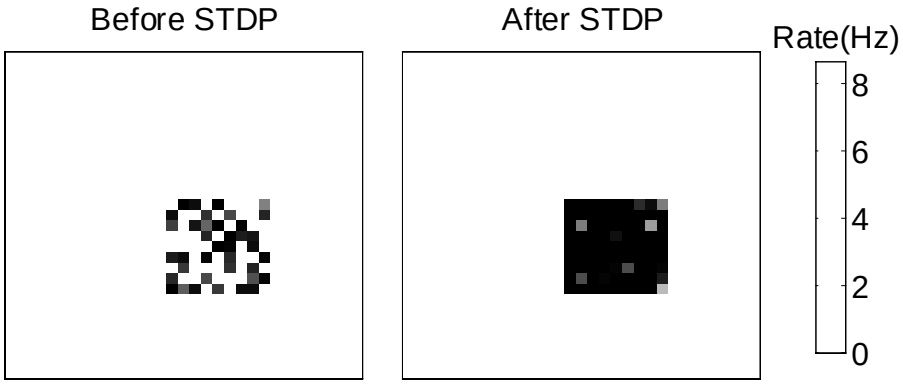
Associative Memory—II



Potentiated synapses between neurons in a pattern enable full recall

Fraction recalled increases faster than fraction stimulated.
Sparseness improves recall (and memory capacity).
Active dendrites also reduce overlap between patterns.

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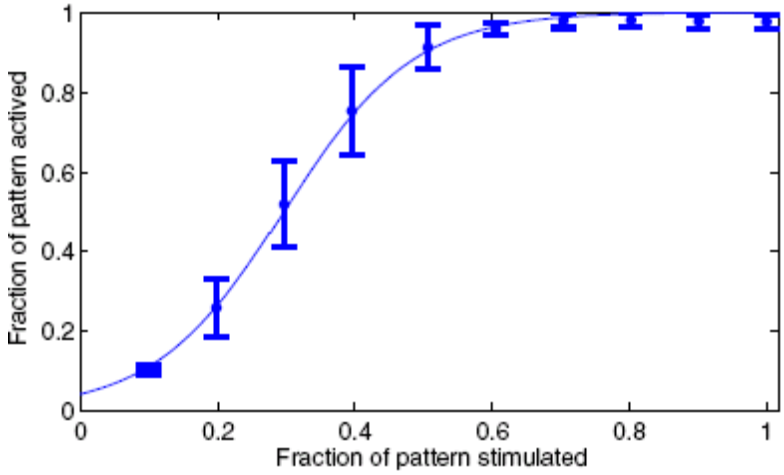
Recall performance

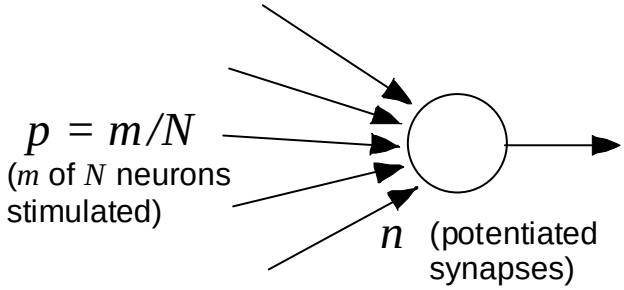


Over 90% of a pattern is recalled when half of its neurons are stimulated.

The stimulated group recruits neurons that have a sufficient number of potentiated synapses.

These neurons may in turn recruit more neurons—this requires a high degree of connectivity.

Simple model of recall



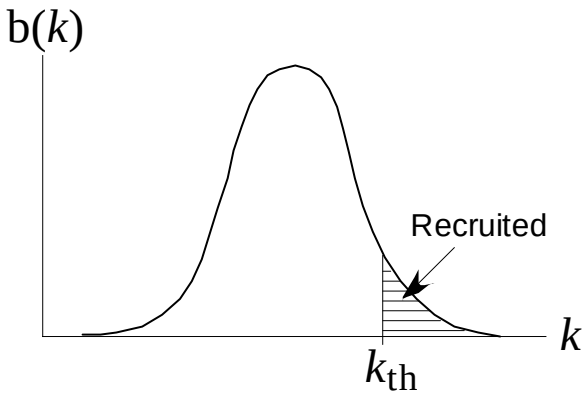
Fraction of potentiated synapses activated equals the fraction of pattern stimulated.

The number of a neuron's potentiated synapses that are activated, **k** , is modeled as a binomial distribution, with density:

$$b[k, n, p] = \binom{n}{k} p^k (1-p)^{n-k}$$

where **p** is the fraction of the pattern stimulated and **n** is the total number of potentiated synapses.

Probability a neuron is recruited



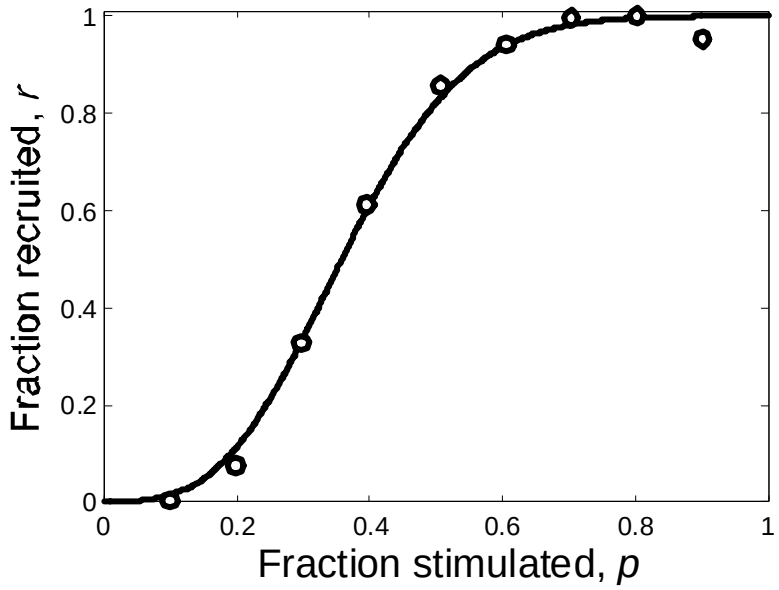
A neuron fires if the number of synapses activated exceeds k_{th}.

The cumulative distribution, **B[k,n,p]**, yields the probability a neuron is recruited:

$$r = 1 - B[k_{th}, n, p]$$

where k_{th} is the minimum number of synapses that must be activated.

Recruited versus stimulated fractions



Binomial distribution yields a good fit with $n = 16$ and $k_{th} = 5.6$.

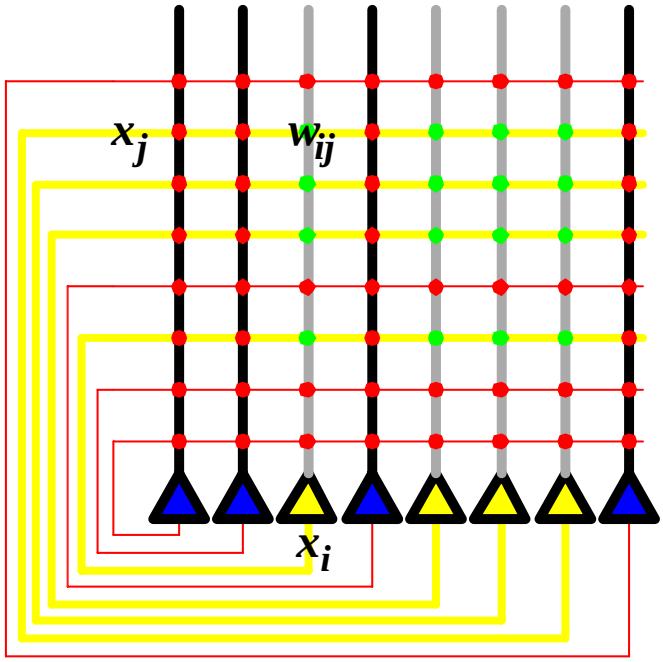
Note that the stimulated and recruited fractions sum to give the fraction of the pattern recalled:

```
f = p + (1 - p) r
```

This relation was used to obtained the points plotted above (**r**) from the measured data (**f**):

```
r = (f - p) / (1 - p)
```

Multiple patterns



Neuron j drives neuron i through a synapse with strength w_{ij}.

In a network with Hebbian synapses, their strengths (probability of potentiation) are given by:

$$w_{ij} = \sum_m x_i^m x_j^m$$

where x_i^m and x_j^m are the activities of neurons i and j when pattern m is presented.

Recalls superposition of stored patterns

The input each neuron i receives is given by

$$u_i = \sum_j w_{ij} x_j = \sum_j \left(\sum_m x_i^m x_j^m \right) x_j$$

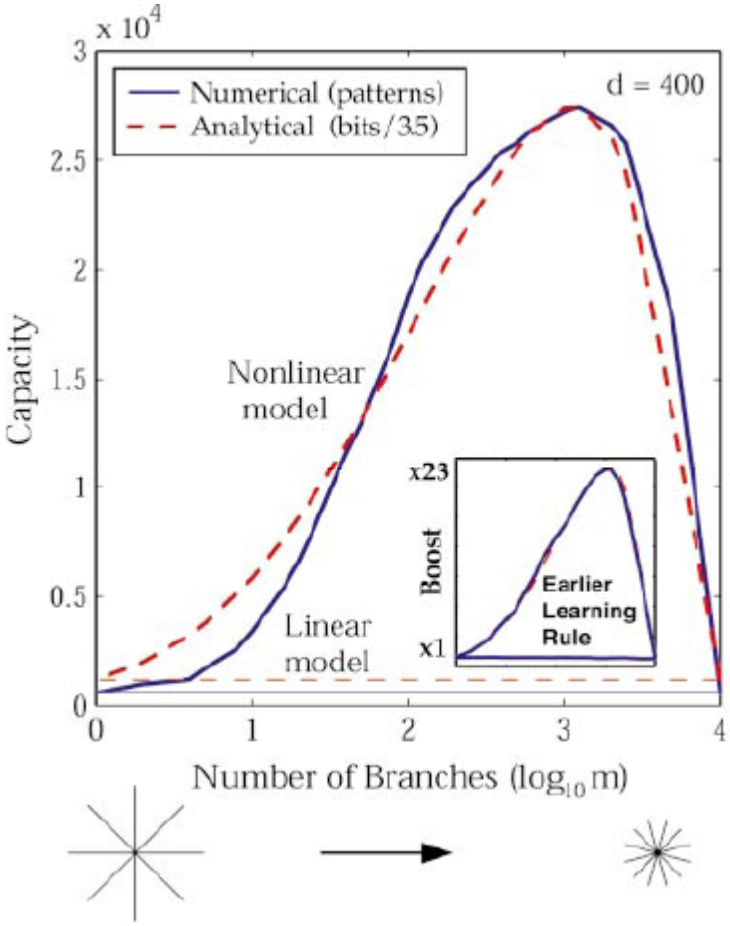
Interchanging the order of summation yields

$$u_i = \sum_m \left(\sum_j x_j^m x_j \right) x_i^m$$

The inner sum is large if the neurons' activity (x_j) overlaps with that invoked by pattern m (x_j^m).

Thus, the network superpimposes the patterns, each weighted by its similarity to the present state.

Reducing superposition: Active dendrites



Memory capacity increases when each dendritic branch acts as nonlinear subunit.