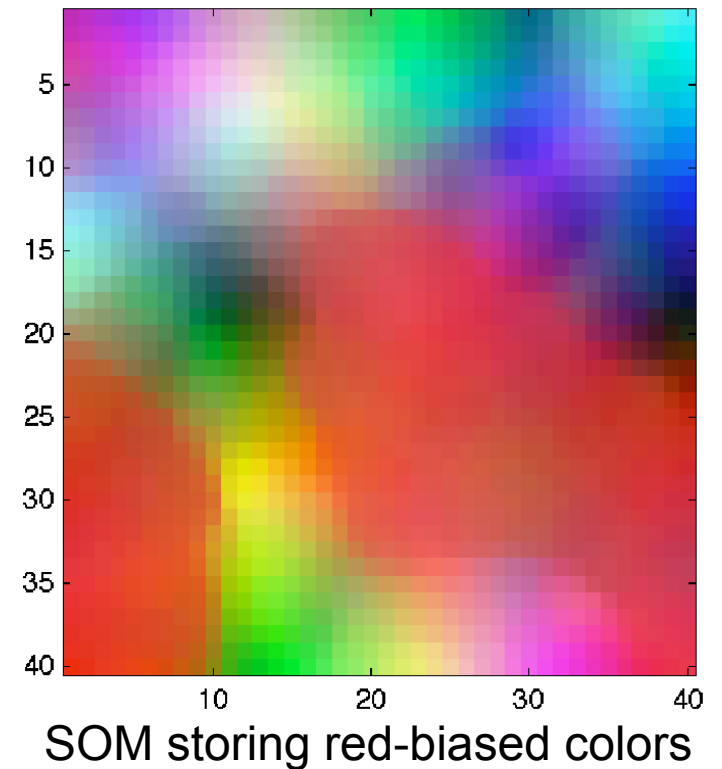


# Self-Managing Associative Memory for Dynamic Acquisition of Expertise in High-Level Domains

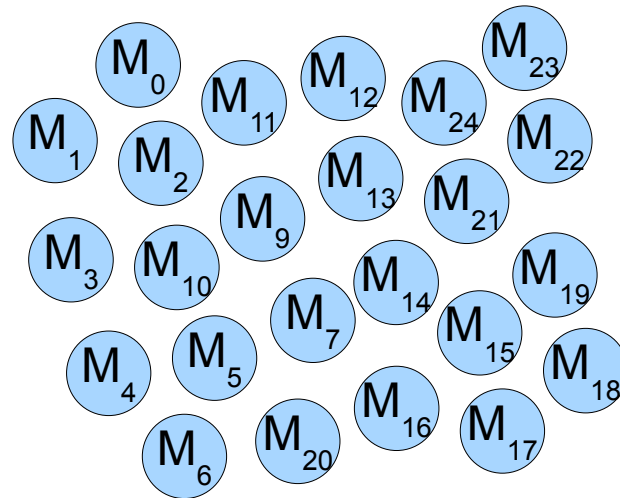
Jacob Beal  
IJCAI 2009

# SOMs as Associative Memory

- Fast, parallel content retrieval
- Generalize to representative models
  - Higher resolution for more frequent categories
- Unsupervised organization of inputs
  - Episodic memory, analogical retrieval, sensory maps
- Dynamics poorly understood



# Self-Organizing Map

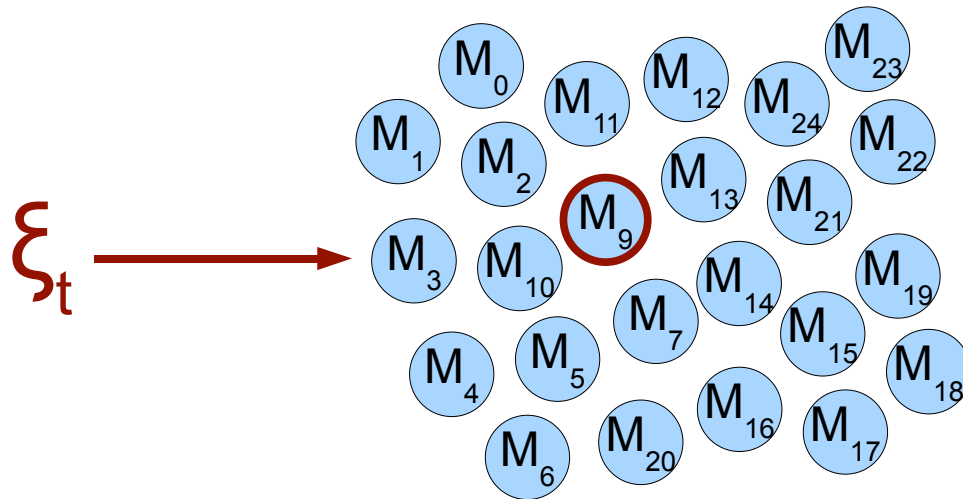


Set of models  $M_i$  arranged in Euclidean space

(normally  $k$ -vectors in a grid)

*Generalization of [Kohonen, '82]*

# Self-Organizing Map

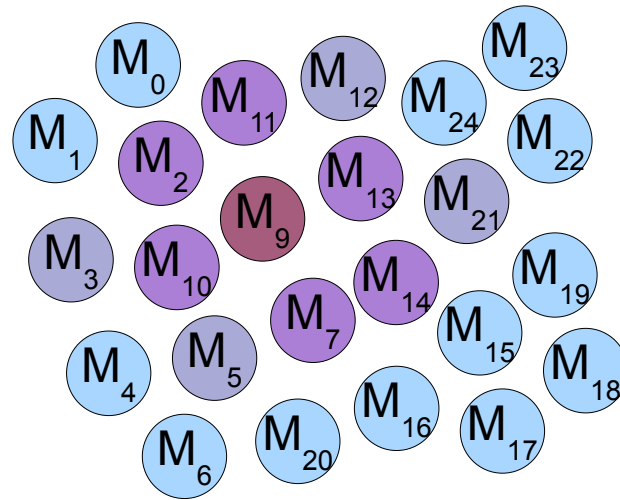


Example  $\xi_t$ : find highest match quality  $Q(M_i, \xi_t)$

(association = match w. incomplete example)

*Generalization of [Kohonen, '82]*

# Self-Organizing Map



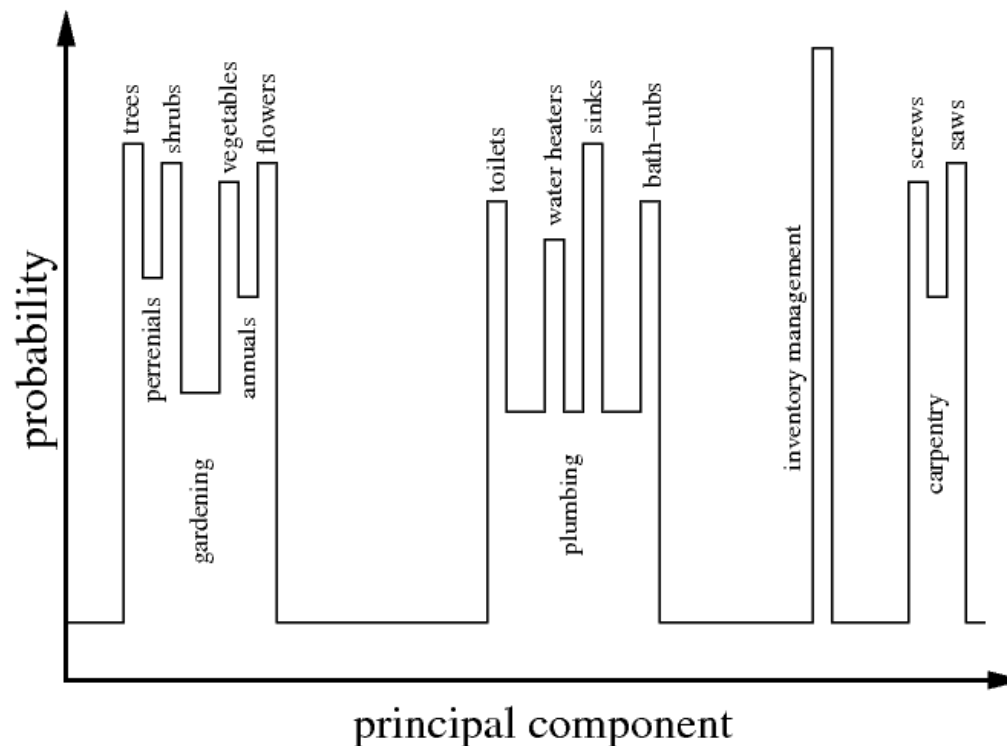
Blend into nearby models with  $B(M_i, \xi_t, w(d(b, i)))$

(initial organization may use time-varying weight)

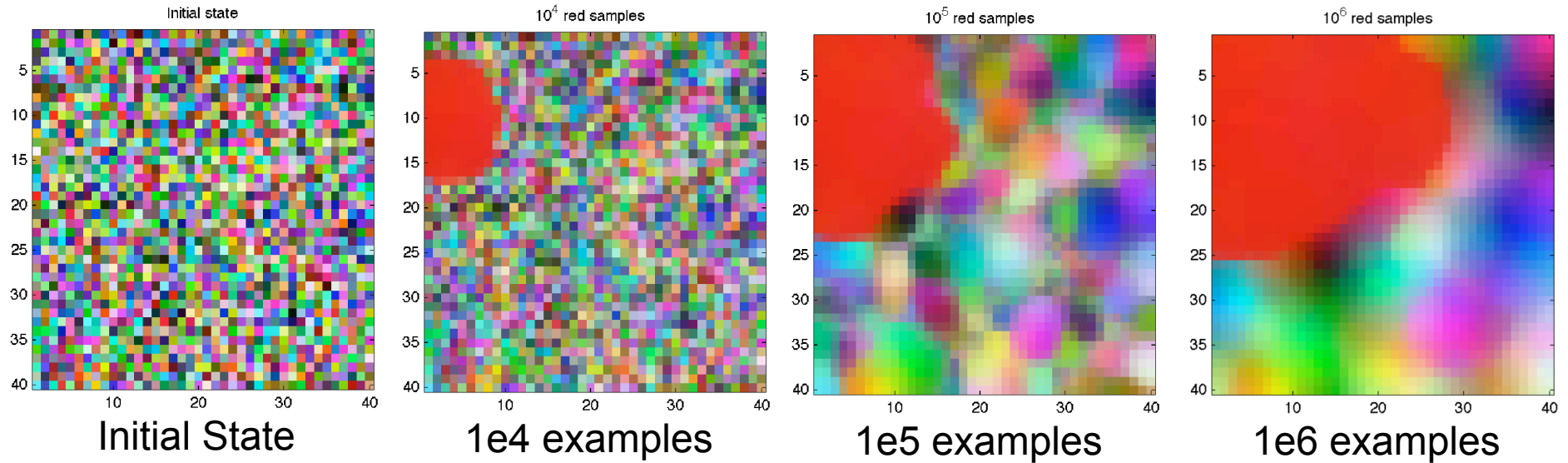
*Generalization of [Kohonen, '82]*

# High-Level Domain Distributions

- Structured high-level models are very sparse
- Assumption: hierarchical clustering → “spikes”
  - $m_i$  = probability of draw from  $i$ th spike



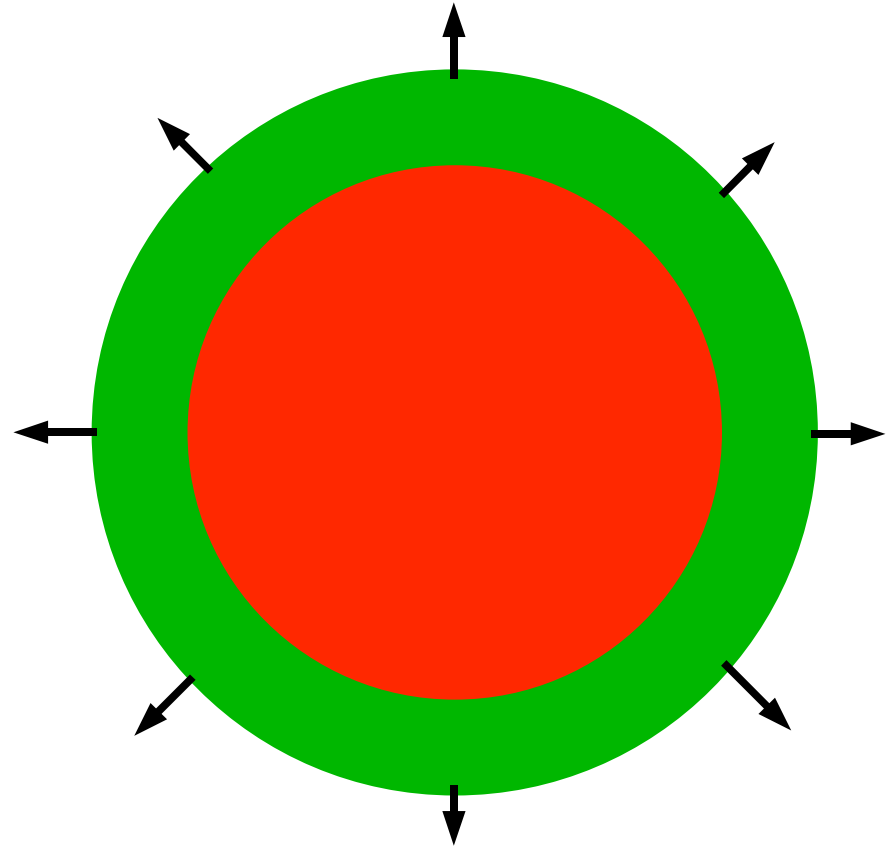
# Growth of a cluster



- Blend: linear,  $w(d) = \max(0, \alpha(1-d/r))$ 
  - Free parameters:  $\alpha, r$

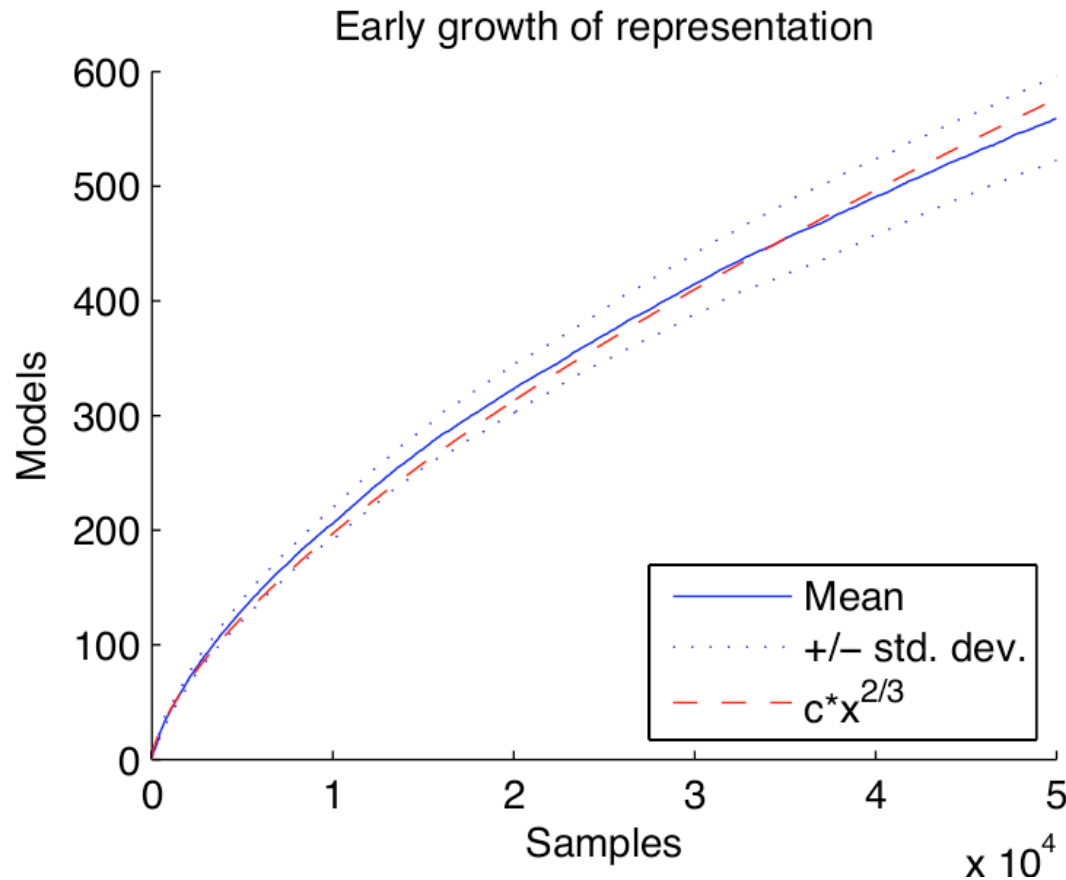
# Analysis of Cluster growth

- Assume homogeneity
  - All growth on boundary
- Unconstrained, size  $n$ 
  - boundary area =  $O(\sqrt{n})$
  - $dn/dt = k/\sqrt{n} \rightarrow O(t^{2/3})$
  - Linear in  $\alpha, r, m_0$
- Eventual equilibrium
  - Size based only on  $m_i$
  - Converge exponentially



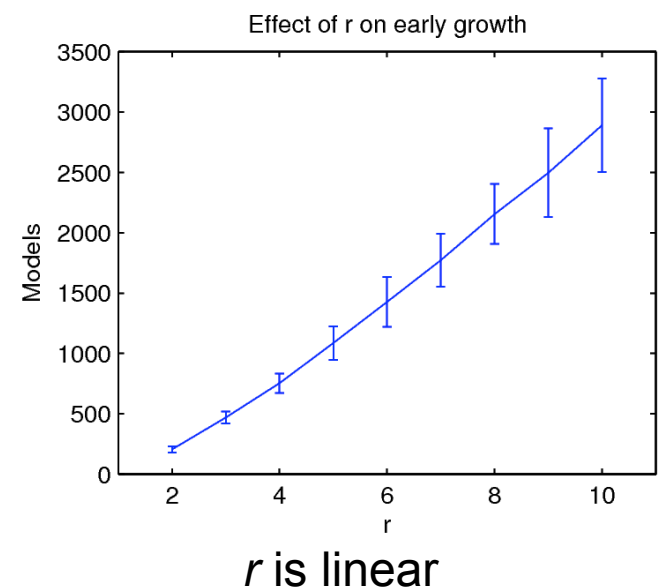
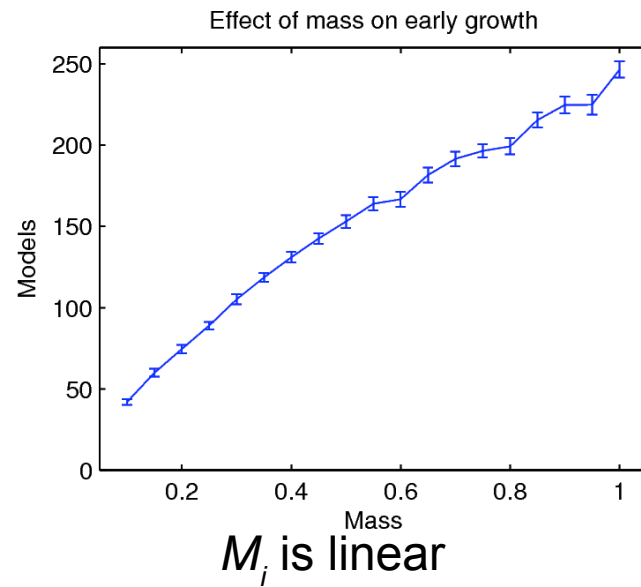
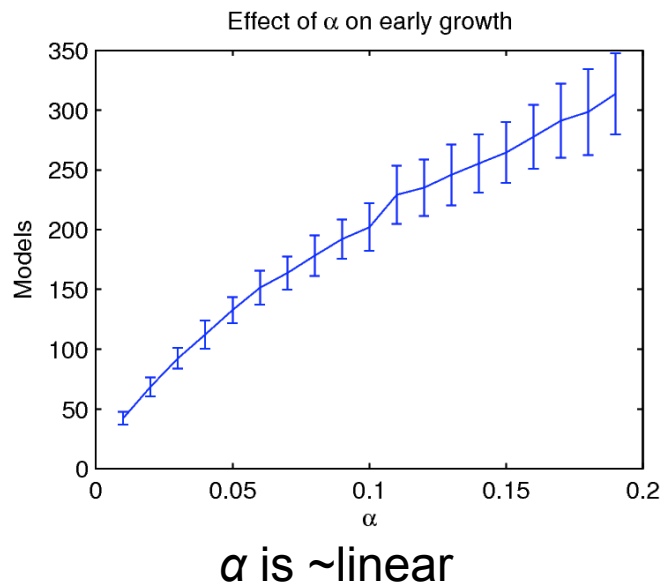


# Experiment: Initial Growth



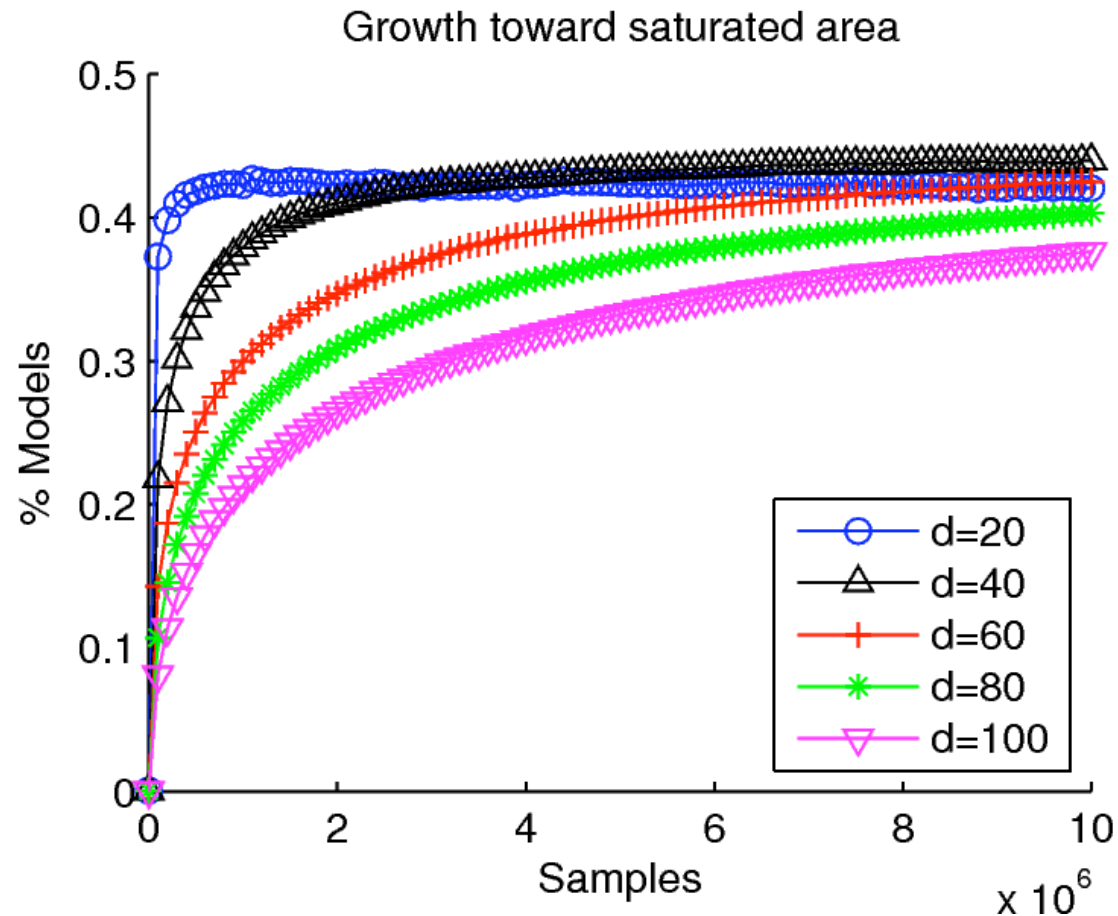
- 100x100 SOM, 40 trials,  $5 \times 10^4$  examples

# Experiment: Initial Growth



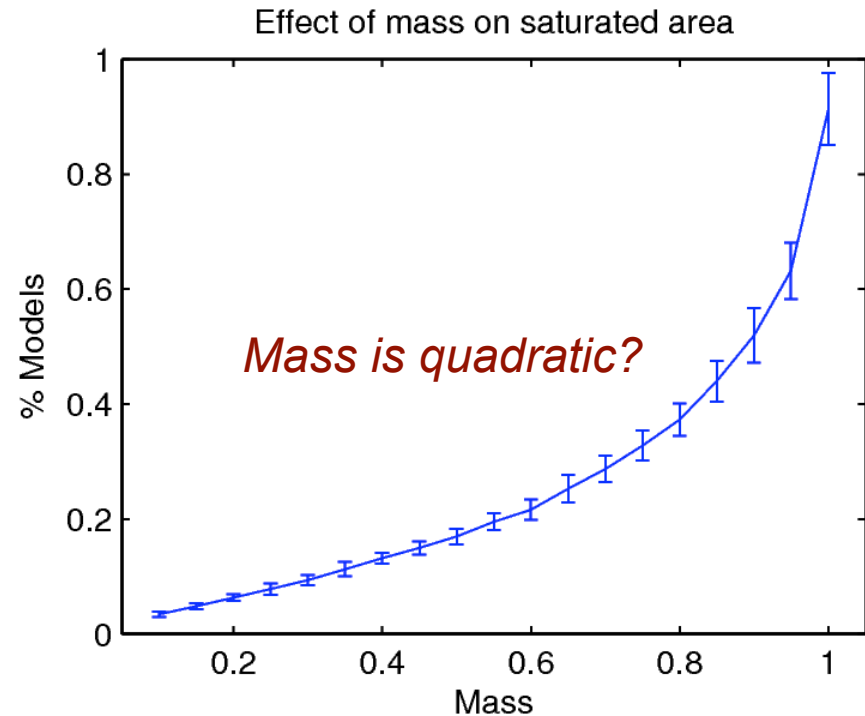
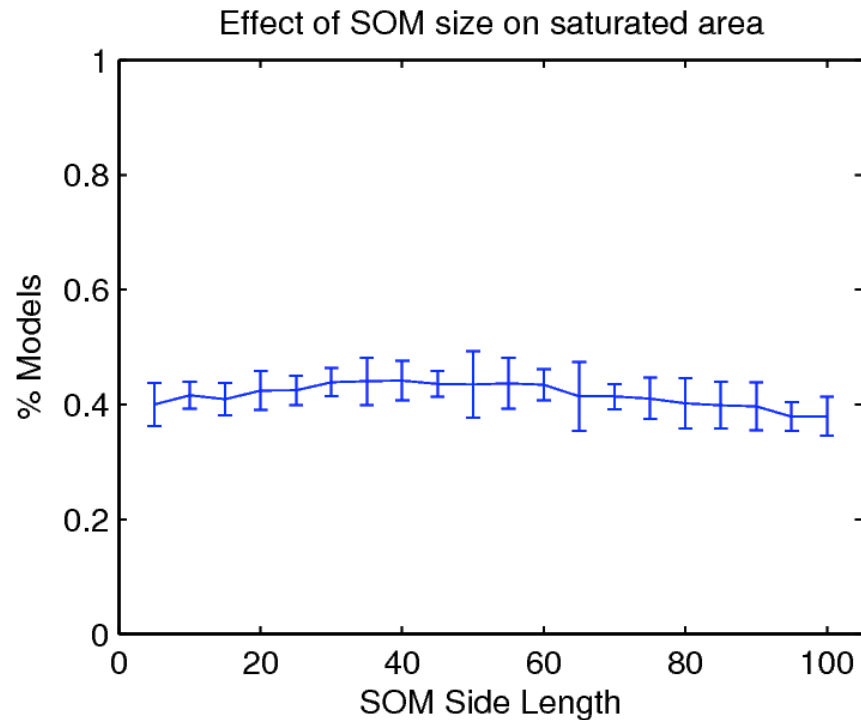
- 100x100 SOM, 40 trials,  $5 \times 10^4$  examples

# Experiment: Convergence



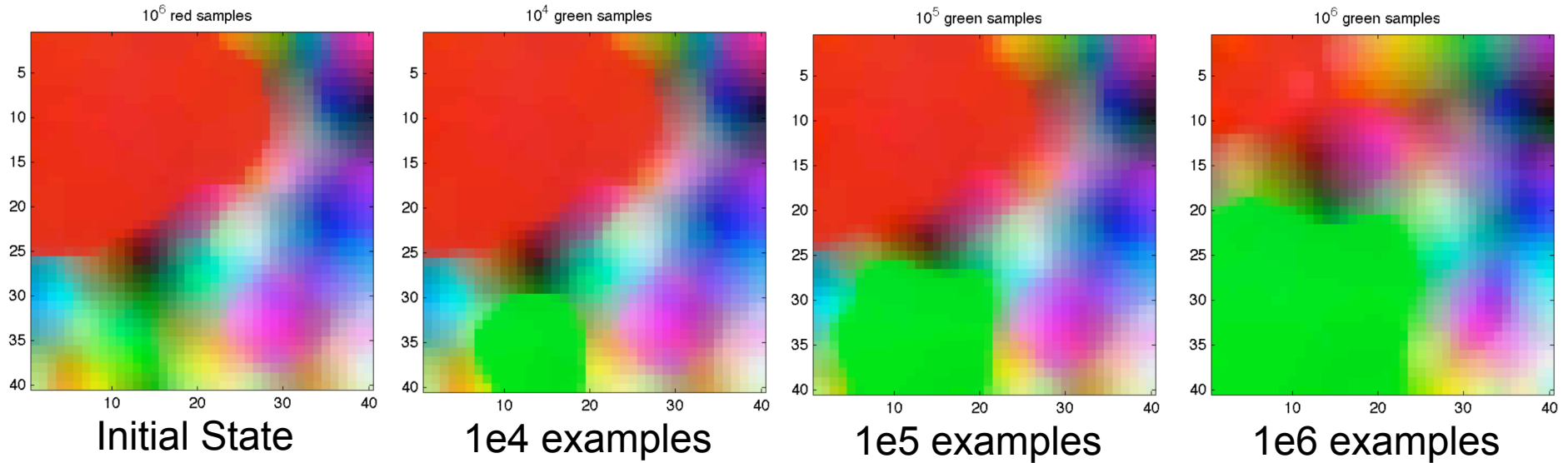
- 100x100 SOM, 40 trials,  $10^7$  examples

# Experiment: Convergence



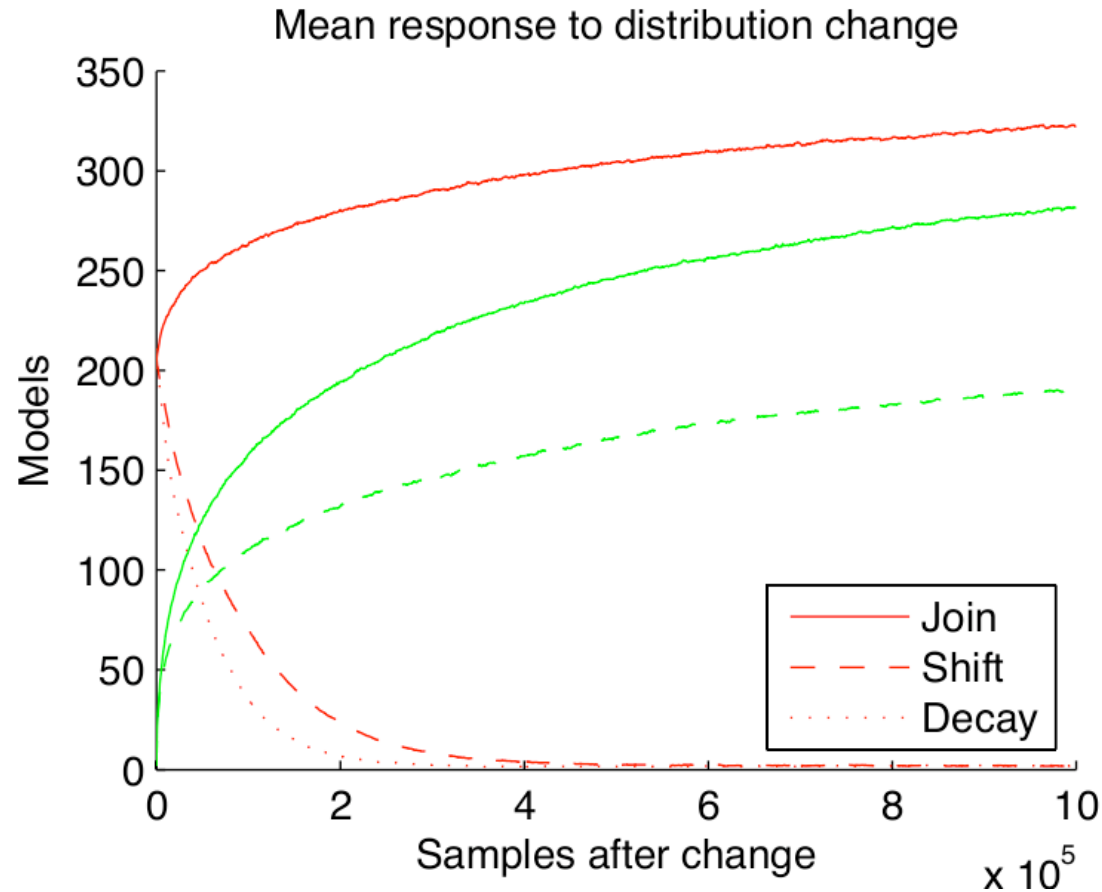
- 100x100 SOM, 40 trials,  $10^7$  examples

# Change of distribution



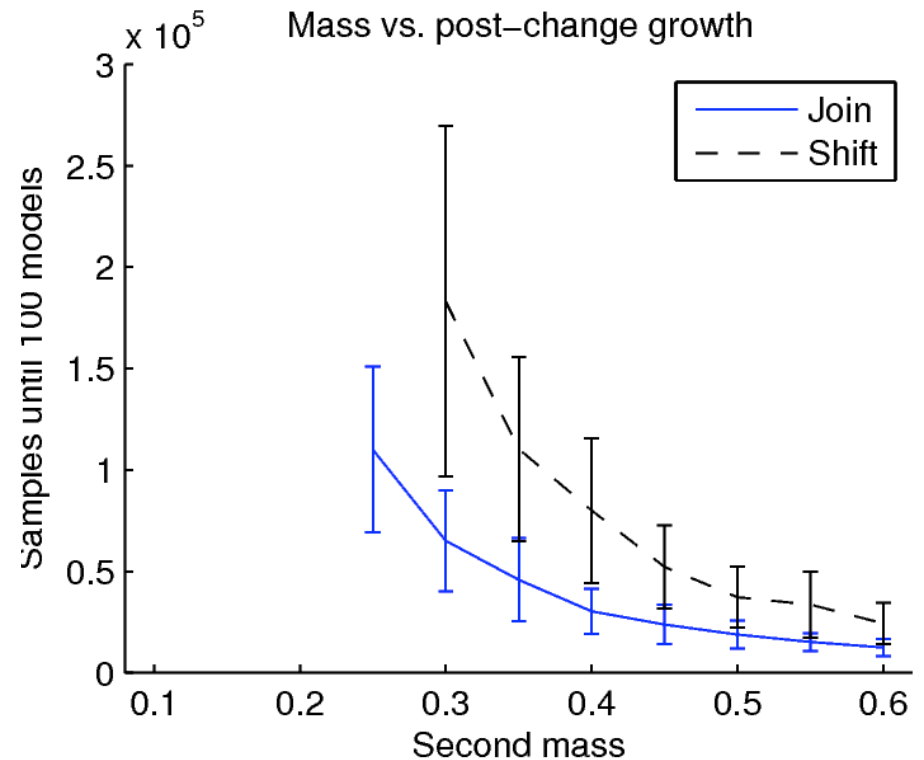
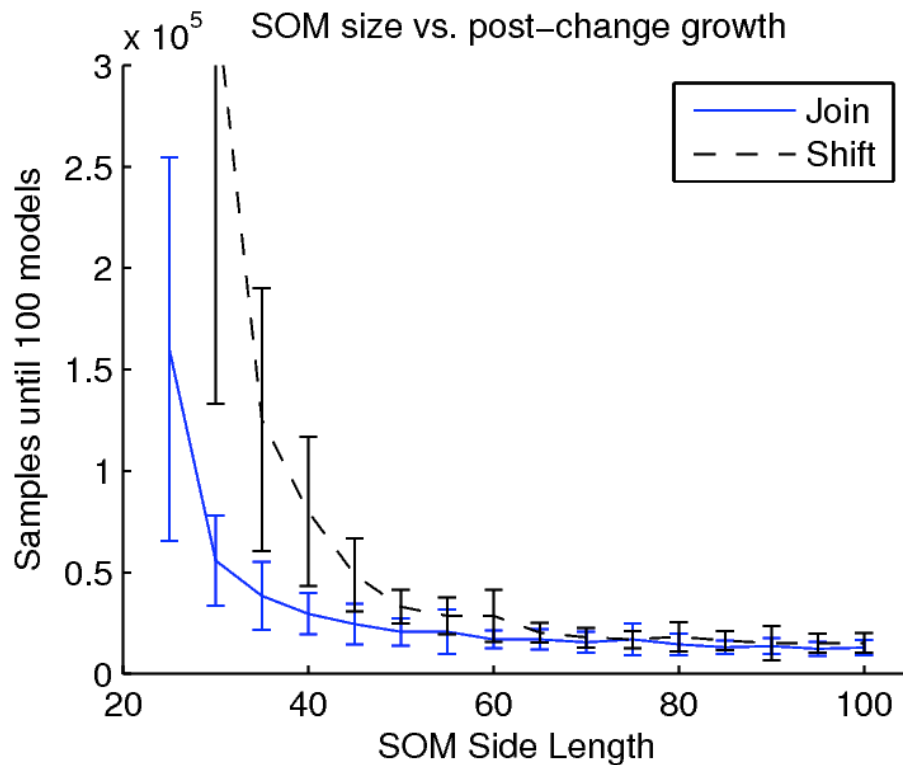
- Experiment with three cases:
  - Join: green added to red
  - Shift: green instead of red
  - Decay: no spike

# Dynamics: Time Response



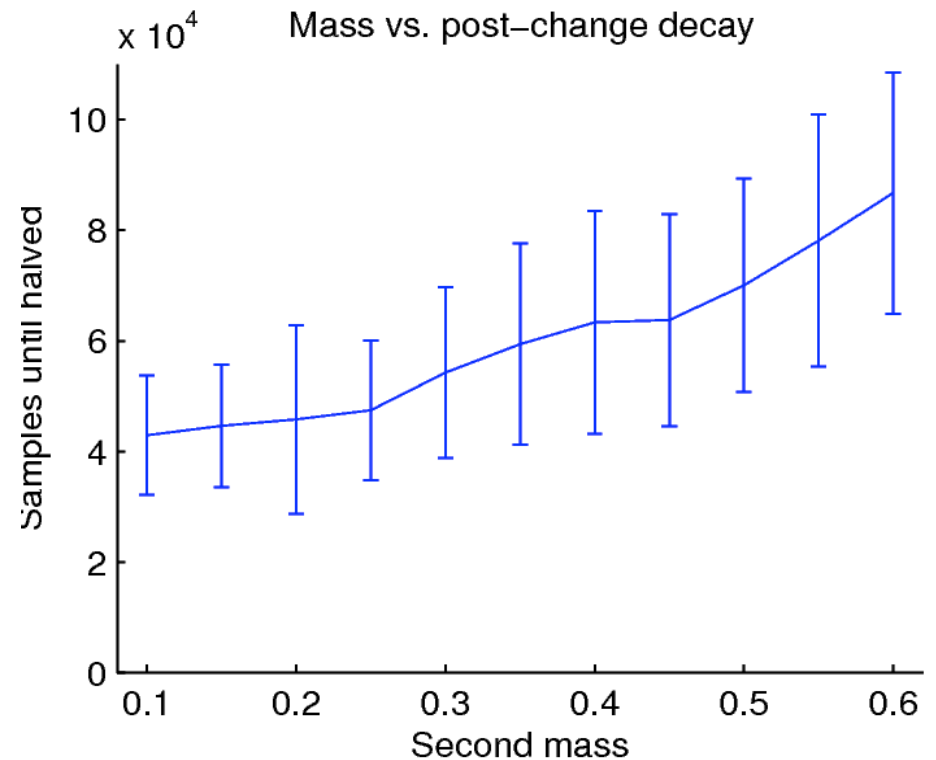
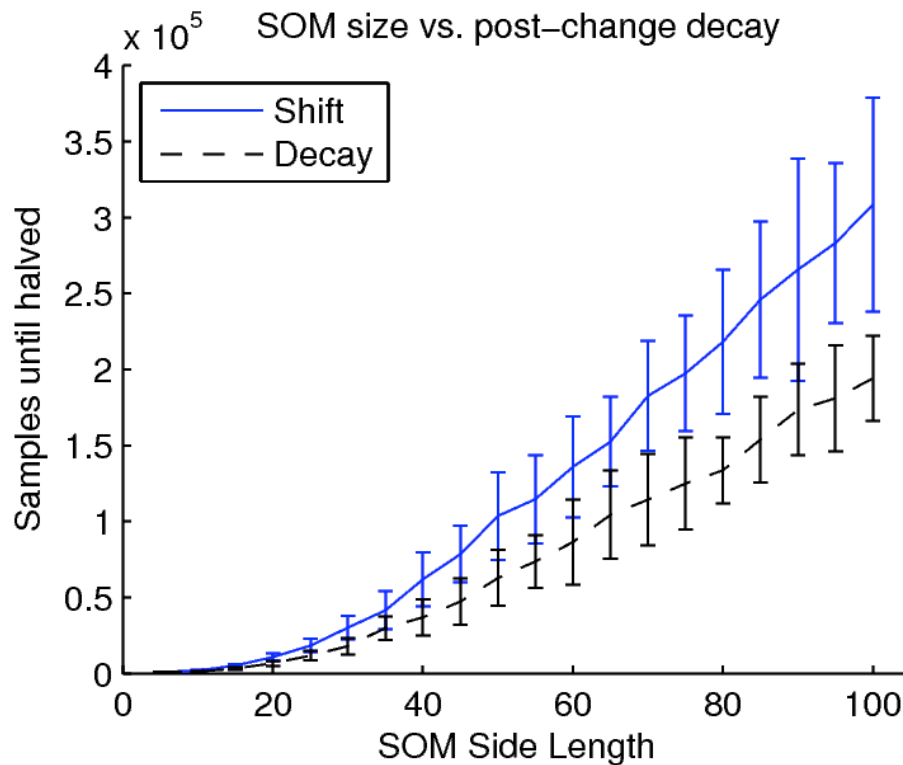
- 40x40 SOM, 40 trials,  $10^6$  old then  $10^6$  new

# Dynamics: Parameter Variation



- Large SOMs grow similarly;  $m_2$  speeds growth

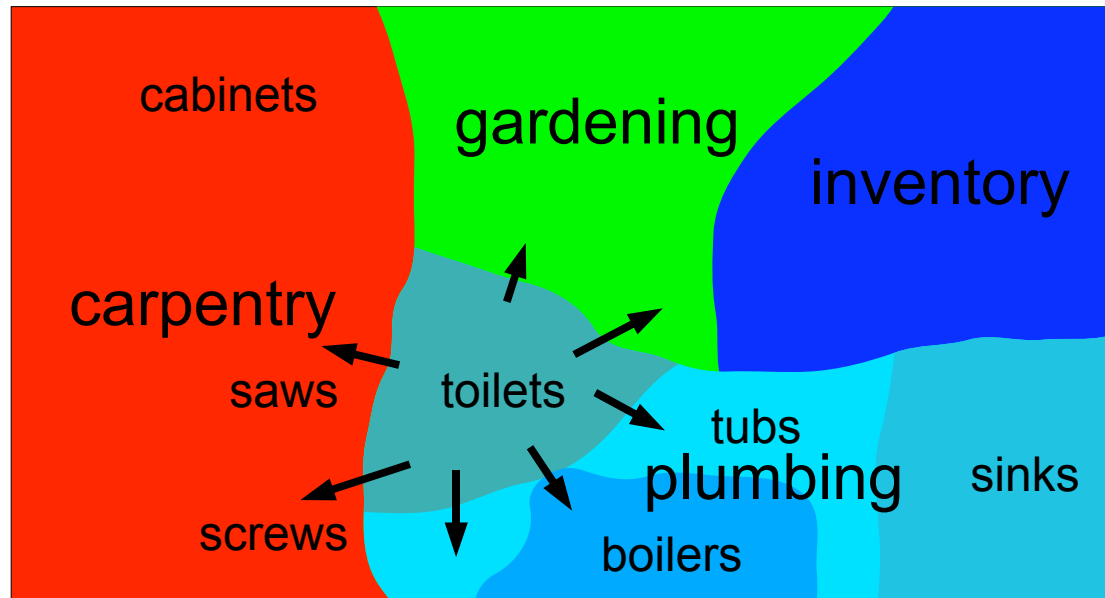
# Dynamics: Parameter Variation



- Large SOMs decay slower;  $m_2$  slows decay



# Erosion of Prior Knowledge



- New knowledge erodes the old unevenly
  - More similar knowledge is more likely to be lost

# Contributions

- Analytic and experimental measure of SOM dynamics for high-level associative memory:
  - Growth of expertise set by boundary interactions
  - Initial  $O(t^{2/3})$  growth fast enough w. high sample rate
  - Growth/decay ratio can support long-term retention of expertise
- Learning erodes prior knowledge unevenly