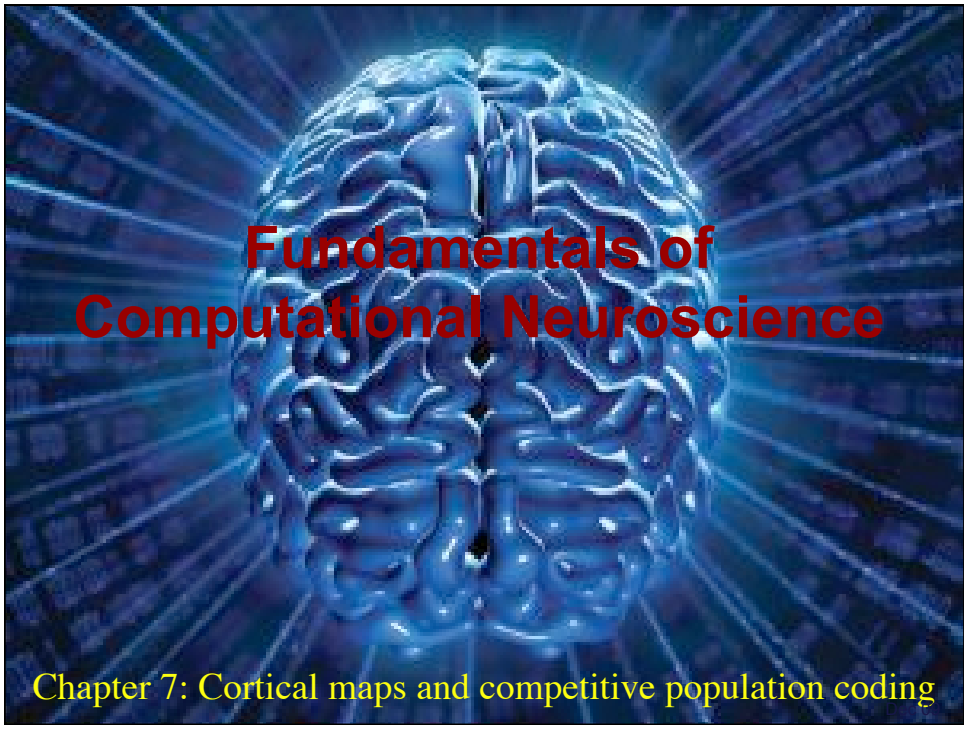


1

som.m

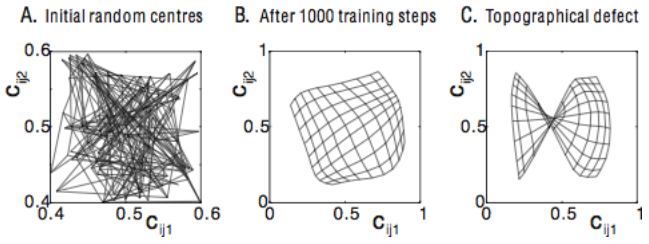
```
%% Two dimensional self-organizing feature map al la Kohonen
 clear; nn=10; lambda=0.2; sig=2; sig2=1/(2*sig^2);
 [X,Y]=meshgrid(1:nn,1:nn); ntrial=0;

 % Initial centres of prefered features:
 c1=0.5-.1*(2*rand(nn)-1);
 c2=0.5-.1*(2*rand(nn)-1);

%% training session
 while(true)
    if(mod(ntrial,100)==0) % Plot grid of feature centres
        clf; hold on; axis square; axis([0 1 0 1]);
        plot(c1,c2,'k'); plot(c1',c2','k');
        tstring=[int2str(ntrial) ' examples']; title(tstring);
        waitforbuttonpress;
    end
    r_in=[rand;rand];
    r=exp(-(c1-r_in(1)).^2-(c2-r_in(2)).^2);
    [rmax,x_winner]=max(max(r)); [rmax,y_winner]=max(max(r'));
    r=exp(-((X-x_winner).^2+(Y-y_winner).^2)*sig2);
    c1=c1+lambda*r.*(r_in(1)-c1);
    c2=c2+lambda*r.*(r_in(2)-c2);
    ntrial=ntrial+1;
 end
```

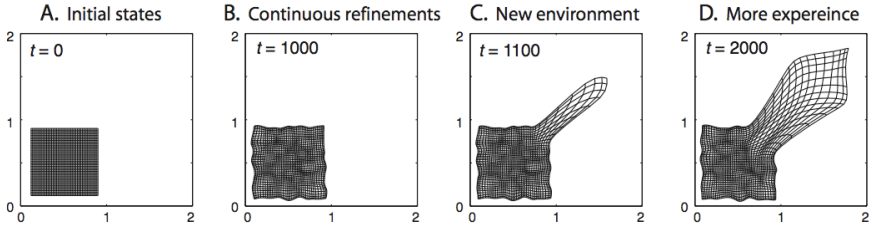
2

SOM simulations



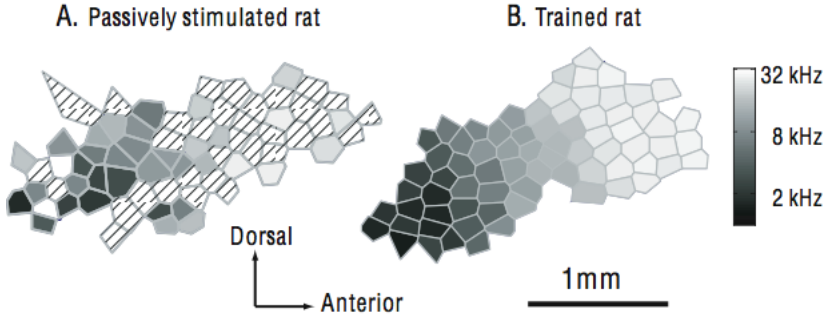
3

Another example



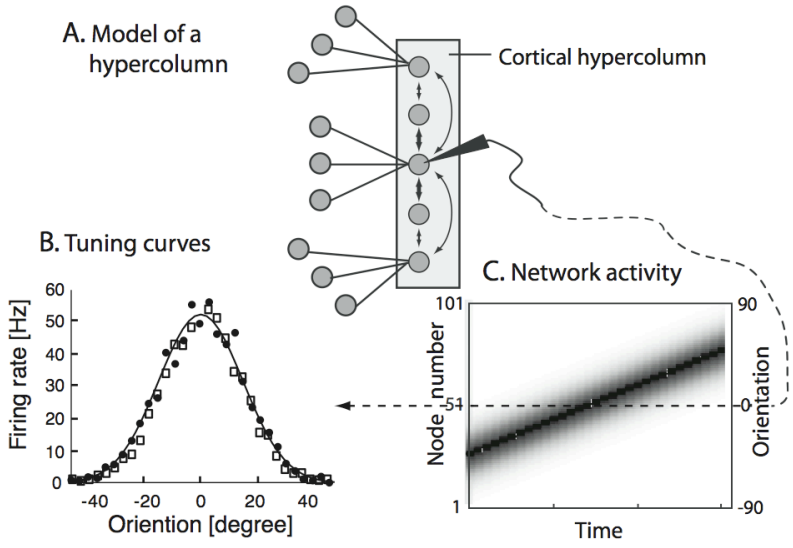
4

Zhou and Merzenich, PNAS 2007



5

Tuning curves



6

Network equations

Update rule of (recurrent) cortical network:

$$\tau \frac{\mathrm{d}u_i(t)}{\mathrm{d}t} = -u_i(t) + \frac{1}{N}\sum_j w_{ij} r_j(t) + \frac{1}{M}\sum_k w^{\mathrm{in}}_{ik} r^{\mathrm{in}}_k(t)$$

Activation function: $r_j(t) = \frac{1}{1+e^{\beta(u_j(t) \quad \alpha)}}$.

Lateral weight matrix: $w_{ij} \propto r_i r_j$

$$= A_{\mathrm{w}} \left(\mathrm{e}^{-((i-j)*\Delta x)^2 \ /2\sigma^2} - C \right)$$

Input weight matrix: $w^{\mathrm{in}}_{ij} \propto r_i r^{\mathrm{in}}_j$

7

Dynamic Neural Field (DNF) Theory

Field dynamics:

$$\tau \frac{\partial \mathbf{u}(\mathbf{x},t)}{\partial t} = -\mathbf{u}(\mathbf{x},t) + \int_{\mathbf{y}} \mathbf{w}(\mathbf{x},\mathbf{y})\mathbf{r}(\mathbf{y},t)\mathrm{d}\mathbf{y} + I^{\mathrm{ext}}(\mathbf{x},t)$$

$$\mathbf{r}(\mathbf{x},t) = g(\mathbf{u}(\mathbf{x},t)),$$

Continuous version of equations above with discretization:

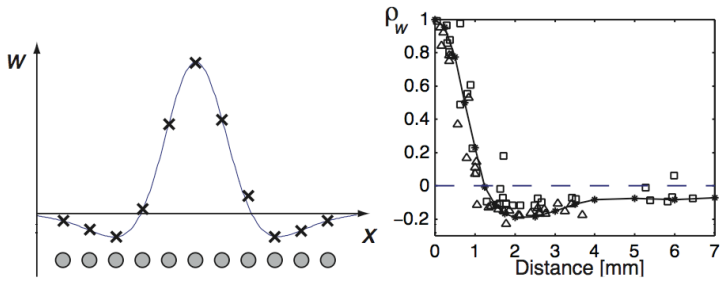
$$x \to i\Delta x \ \text{ and } \ \int \mathrm{d}x \to \Delta x \sum$$

8

Lateral weight kernel

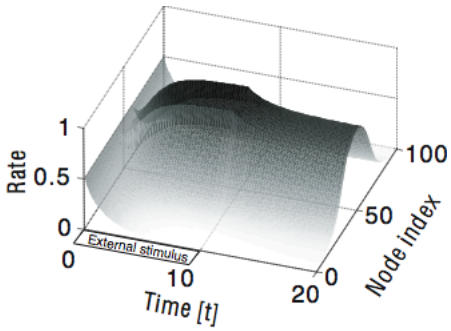
$$\mathbf{w}^{\mathrm{E}}(|x-y|) = A_{\mathrm{w}} \mathrm{e}^{-(x-y)^2/4\sigma_r^2}$$

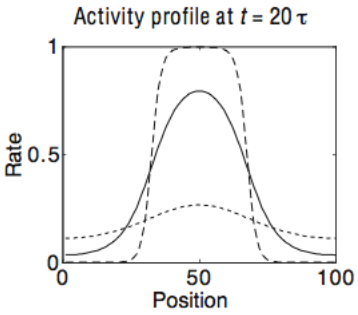
Can be learned from Gaussian response curves of individual nodes



9

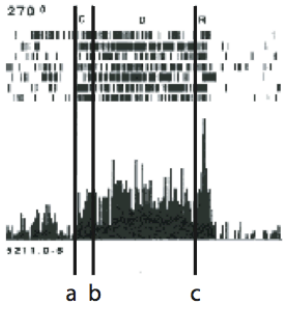
Self-sustained activity packet



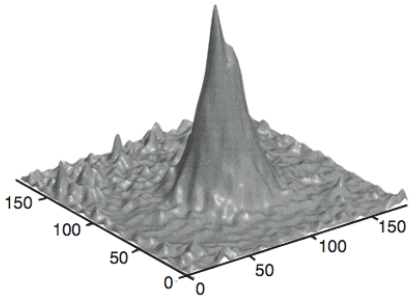


10

DNF example



PFC (Funahashi, Bruce & Goldman-Rakic, 1989)



Hippocampus (Samsonovich & McNaughton, 1997)

11

dnf.m

```
%% Dynamic Neural Field Model (1D)
 clear; clf; hold on;
 nn = 100; dx=2*pi/nn; sig = 2*pi/10; C=0.5;

%% Training weight matrix
 for loc=1:nn;
     i=(1:nn)'; dis= min(abs(i-loc),nn-abs(i-loc));
     pat(:,loc)=exp(-(dis*dx).^2/(2*sig^2));
 end
 w=pat*pat'; w=w/w(1,1); w=4*(w-C);
%% Update with localised input
 tall = []; rall = [];
 I_ext=zeros(nn,1); I_ext(nn/2-floor(nn/10):nn/2+floor(nn/10))=1;
 [t,u]=ode45('rnn_ode',[0 10],zeros(1,nn),[],nn,dx,w,I_ext);
 r=1./(1+exp(-u)); tall=[tall;t]; rall=[rall;r];
%% Update without input
 I_ext=zeros(nn,1);
 [t,u]=ode45('rnn_ode',[10 20],u(size(u,1),:),[],nn,dx,w,I_ext);
 r=1./(1+exp(-u)); tall=[tall;t]; rall=[rall;r];
%% Plotting results
 surf(tall',1:nn,rall','linestyle','none'); view(0,90);
```

12

rnn.ode

```
1   function udot=rnn_ode(t,u,flag,nn,dx,w,I_ext)
2   % odefile for recurrent network
3    tau_inv = 1.;      % inverse of membrane time constant
4    r=1./(1+exp(-u));
5    sum=w*r*dx;
6    udot=tau_inv*(-u+sum+I_ext);
7   return
```

Update rule of (recurrent) cortical network:

$$\tau \frac{du_i(t)}{dt} = -u_i(t) + \frac{1}{N}\sum_j w_{ij} r_j(t) + \frac{1}{M}\sum_k w_{ik}^{\text{in}} r_k^{\text{in}}(t)$$

Activation function: $r_j(t) = \frac{1}{1+e^{\beta(u_j(t) \quad \alpha)}}$.

13

Further readings

Teuvo Kohonen (1989), **Self-organization and associative memory**, Springer Verlag, 3rd edition.

David J. Willshaw and Christoph von der Malsburg (1976), **How patterned neural connexions can be set up by self-organisation**, in **Proc Roy Soc** B 194, 431–445.

Shun-ichi Amari (1977), **Dynamic pattern formation in lateral-inhibition type neural fields**, in **Biological Cybernetics** 27: 77–87.

Huge R. Wilson and Jack D. Cowan (1973), **A mathematical theory of the functional dynamics of cortical and thalamic nervous tissue**, in **Kybernetik** 13:55-80.

Kechen Zhang (1996), **Representation of spatial orientation by the intrinsic dynamics of the head-direction cell ensemble: A theory**, in **Journal of Neuroscience** 16: 2112–2126.

Simon M. Stringer, Thomas P. Trappenberg, Edmund T. Rolls, and Ivan E.T. de Araujo (2002), **Self-organizing continuous attractor networks and path integration I: One-dimensional models of head direction cells**, in **Network: Computation in Neural Systems** 13:217–242.

Alexandre Pouget, Richard S. Zemel, and Peter Dayan (2000), **Information processing with population codes**, in **Nature Review Neuroscience** 1:125–132.