TSP

$$E = \frac{A}{2} \sum_{\substack{\text{cities} \\ X}} \sum_{i} \sum_{j \neq i} V_i^X V_j^X$$

$$+ \frac{B}{2} \sum_{i} \sum_{\substack{X \\ \text{city}}} \sum_{\substack{Y \neq X \\ \text{city}}} V_i^Y V_i^X$$

$$+ \frac{C}{2} \left(\left(\sum_{X} \sum_{i} V_i^X \right) - n \right)^2$$

$$+ \frac{D}{2} \sum_{X} \sum_{Y \neq X} \sum_{i} d_{XY} V_i^X \left(V_{i+1}^Y + V_{i-1}^Y \right)$$

(note: modulo n on +, −)

(for 10 city problem

Hopfield $A = B = 500$

$C = 200$

$D = 500$

+ a couple other parameters,

(gain, n')

TSP - Energy Function

$$E = -\frac{1}{2} \sum_i \sum_{j \neq i} v_i w_{ij} v_j - \sum \overset{\text{input}}{I_i} v_i + \sum_i \overset{\text{threshold}}{U_i} v_i$$

- Comparable Continuous version.
- Set w_{ij} so that minimizing E minimizes problem.

TSP

$$E = \frac{A}{2}\sum_{X=1}^{n}\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} V_{Xi}V_{Xj}$$ (row 1)

$$+ \frac{B}{2}\sum_{i=1}^{n}\sum_{X=1}^{n}\sum_{\substack{Y=1\\ Y\neq X}}^{n} V_{Xi}V_{Yi}$$ (col 1)

$$+ \frac{C}{2}\left(\sum_{X=1}^{n}\sum_{i=1}^{n} V_{Xi} - n\right)^2$$ (exactly n

$$+ \frac{D}{2}\sum_{X=1}^{n}\sum_{\substack{Y=1\\ Y\neq X}}^{n}\sum_{i=1}^{n} d_{XY}V_{Xi}\left(V_{Y,i+1} + V_{Y,i-1}\right)$$

(min. distance)

HOPFIELD NET

Convergence (Energy Function)

$$E = -\frac{1}{2} \sum_{i \neq j} \sum_{j} w_{ij}$$ [redacted] $$- \sum_{i} x_i y_i + \sum_{i} \theta_i y_i$$

$$\Delta E = -\left[\sum_{j} y_j w_{ij} + x_i - \theta_i \right] \Delta y_i$$

$\vec{x}$ = input
$\vec{y}$ = activation
$\vec{w}$ = weights

lues of the u_{Xi} equal to

re when the network has
at manner, however, has
rium point, much like a
r a slight nudge, the ball
ver, the ball would roll
y adding a random noise
here δu_{Xi} is the random

e nudge determines the
, different random-noise
ferent final stable states.
s earlier in this section,
r than the best solution
s find the best solution
eated trials have shown
the minimum distance.
network would evolve

how both the power and
lso illustrates a general
. finding an appropriate
ost difficult part of the

AM network simulator
lementation of bidirec-
esse, this is a relatively
g the general nature of
nections in a sequential
uctures needed to over-
ur basic simulator. We
s needed to implement

ions

defined for our simula-
nized into layers, with
have decided that the

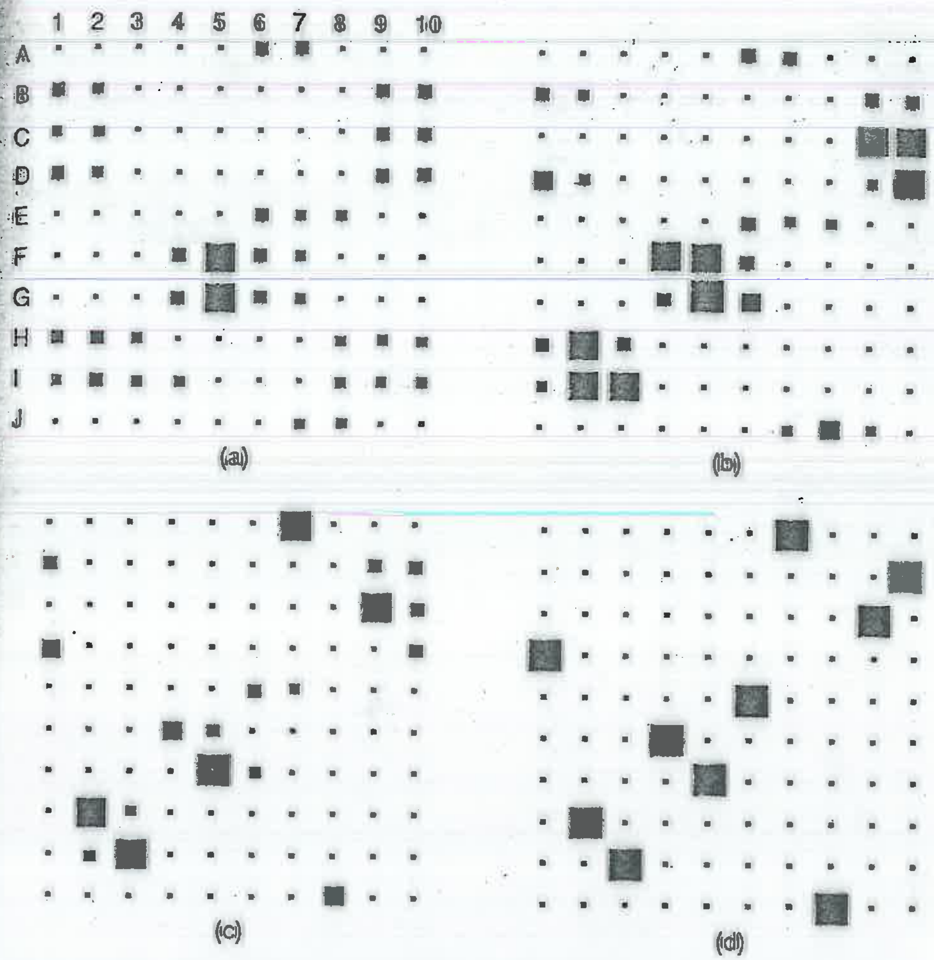
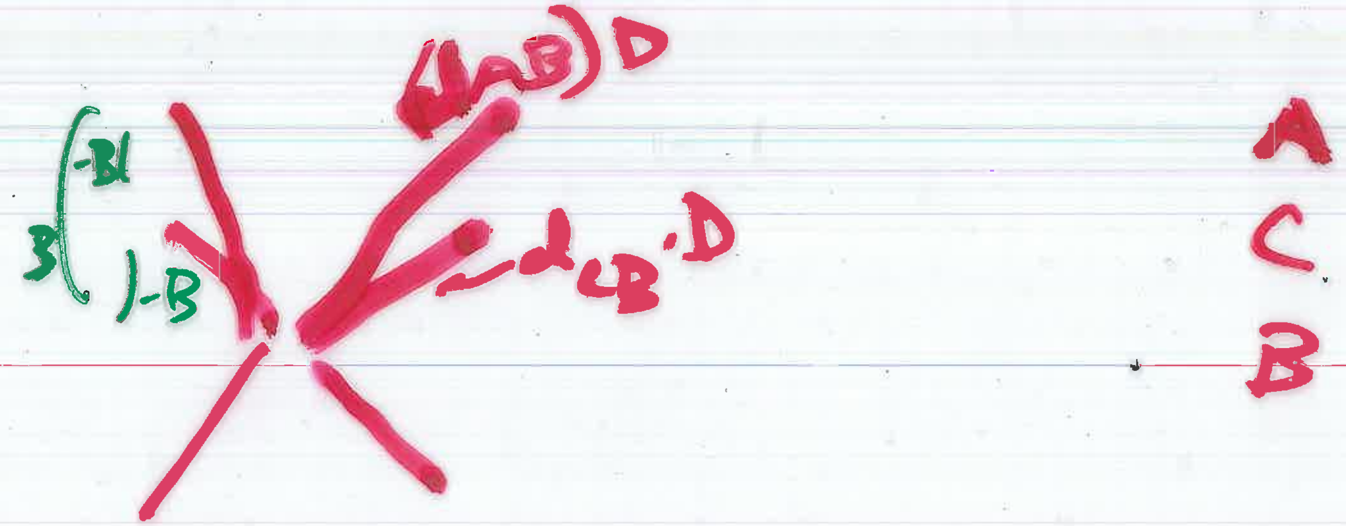


Figure 4.12 This sequence of diagrams illustrates the convergence of the Hopfield network for a 10-city TSP tour. The output values, v_{Xi}, are represented as squares at each location in the output-unit matrix. The size of the square is proportional to the magnitude of the output value. (a, b, c) At the intermediate steps, the system has not yet settled on a valid tour. The magnitude of the output values for these intermediate steps can be thought of as the current estimate of the confidence that a particular city will end up in a particular position on the tour. (d) The network has stabilized on the valid tour, DHIFGEAJCB. *Source: Reprinted with permission of Springer-Verlag, Heidelberg, from J. J. Hopfield and D. W. Tank, "Neural computation of decisions in optimization problems."* Biological Cybernetics, *52:141–152, 1985.*

Lateral inhibition : Same row
Different neurons

weight $-A$



Vertical inhibition: Same row
Different neurons
weight $-B$

TSP

n cities

n^2 neurons

location in tour

city

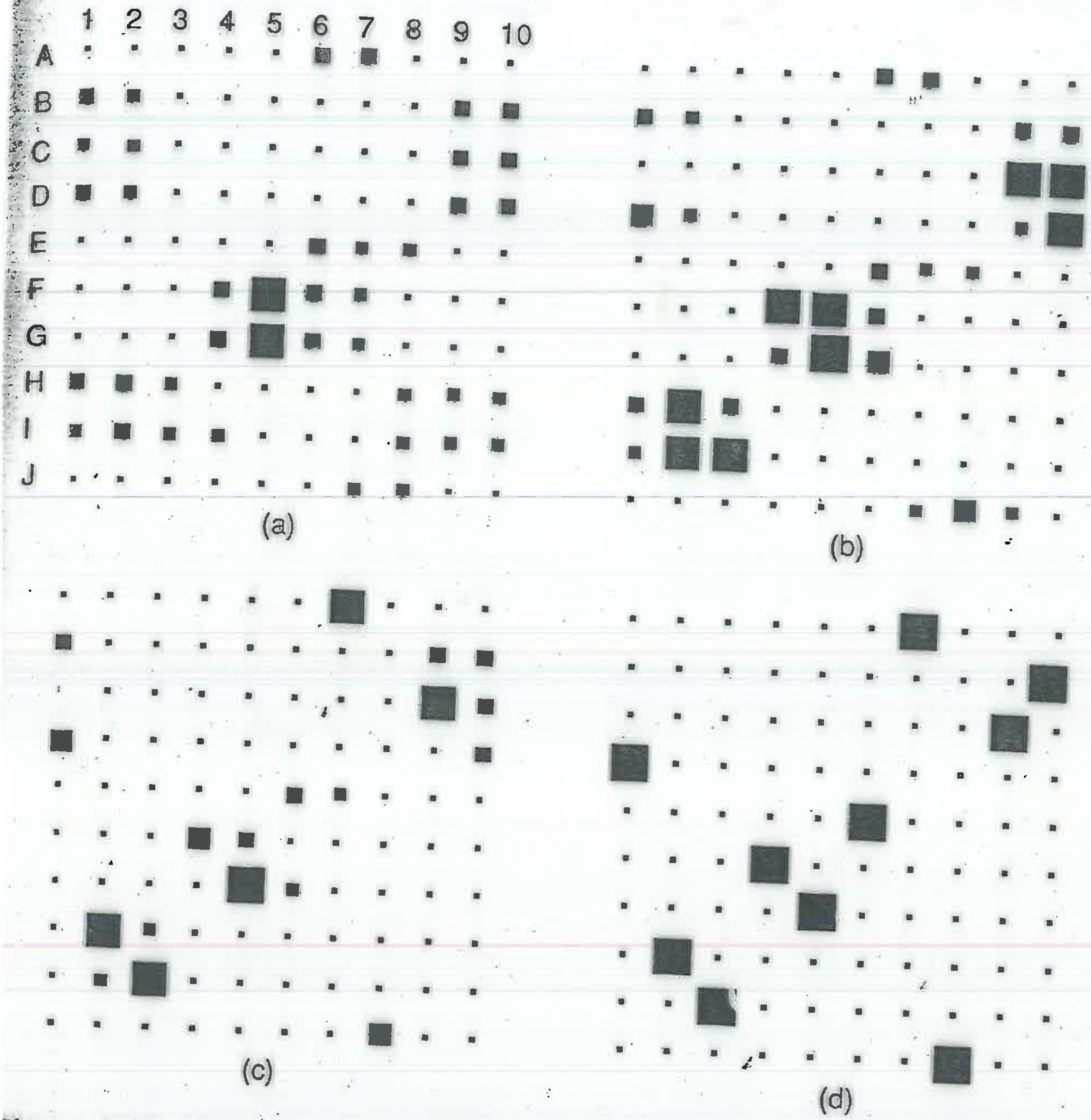


Figure 4.12 This sequence of diagrams illustrates the convergence of the Hopfield network for a 10-city TSP tour. The output values, v_{Xi}, are represented as squares at each location in the output-unit matrix. The size of the square is proportional to the magnitude of the output value. (a, b, c) At the intermediate steps, the system has not yet settled on a valid tour. The magnitude of the output values for these intermediate steps can be thought of as the current estimate of the confidence that a particular city will end up in a particular position on the tour. (d) The network has stabilized on the valid tour, DHIFGEAJCB. *Source: Reprinted with permission of Springer-Verlag, Heidelberg, from J. J. Hopfield and D. W. Tank, "Neural computation of decisions in optimization problems."* Biological Cybernetics, *52:141–152, 1985*.

Global inhibition $- c$
(keeps $\neq 0$)

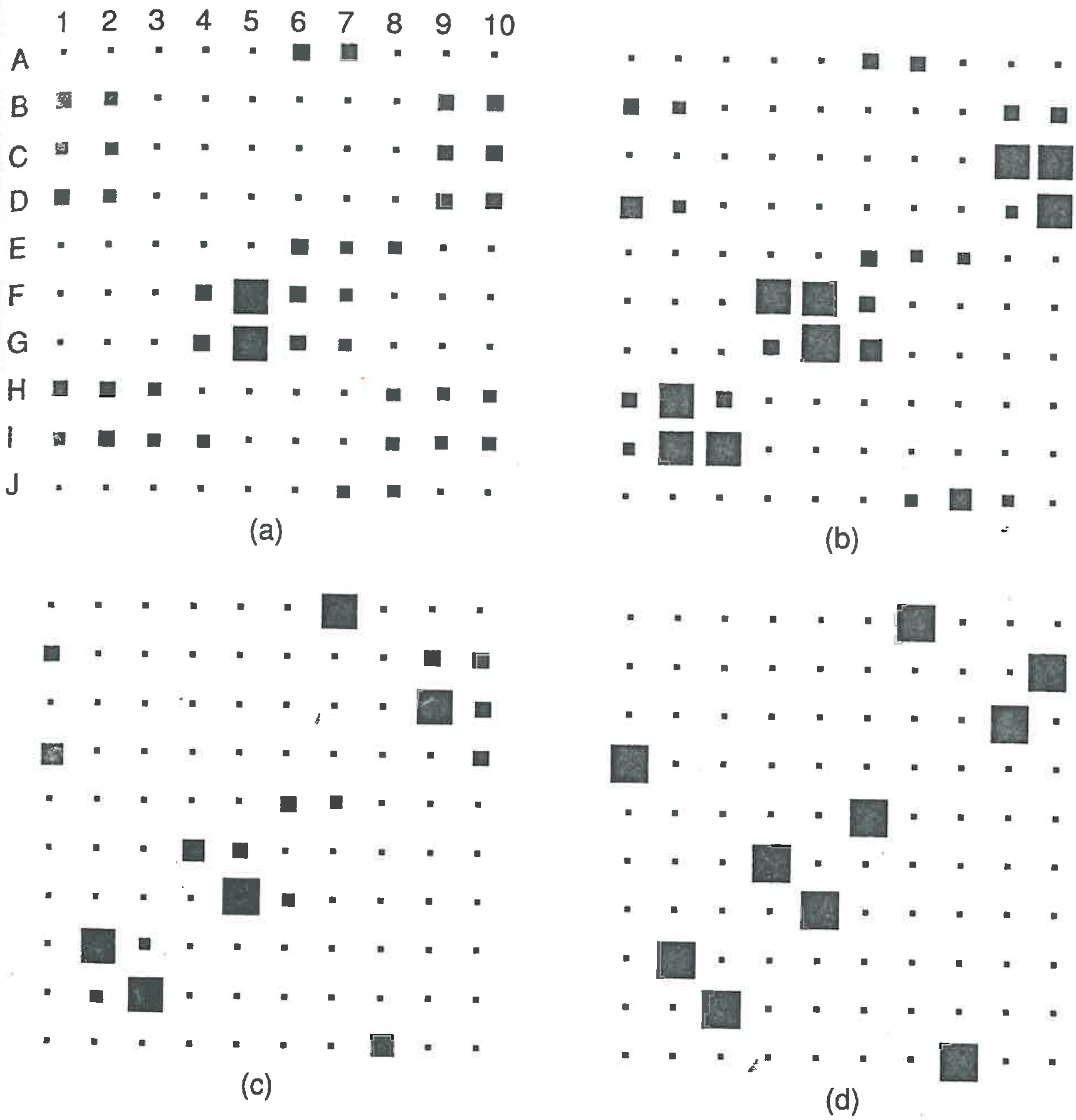


Figure 4.12 This sequence of diagrams illustrates the convergence of the Hopfield network for a 10-city TSP tour. The output values, v_{Xi}, are represented as squares at each location in the output-unit matrix. The size of the square is proportional to the magnitude of the output value. (a, b, c) At the intermediate steps, the system has not yet settled on a valid tour. The magnitude of the output values for these intermediate steps can be thought of as the current estimate of the confidence that a particular city will end up in a particular position on the tour. (d) The network has stabilized on the valid tour, DHIFGEAJCB. *Source: Reprinted with permission of Springer-Verlag, Heidelberg, from J. J. Hopfield and D. W. Tank, "Neural computation of decisions in optimization problems."* Biological Cybernetics, *52:141–152, 1985.*