دانشگاه صنعتی خواجه نصیرالدین طوسی
دانشکده مهندسی برق- گروه مهندسی کنترل

تمرین درس محاسبات نرم

در رشتهٔ مهندسی برق گرایش مهندسی کنترل

عنوان

تمرین کلاسی دوم: بازسازی اعداد از روی اعداد مخدوش یا نویزی‌شده (مثال هگان)

نگارش

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پاسخ سوالات

نکات قابل ذکر

کدهای متلب مربوط به این سوال از داخل پوشهٔ Codes قابل اجراست. هم‌چنین می‌توان از دستور nnd7sh در متلب و کدمنبع آورده‌شده در فهرست شکل‌ها برای شبیه‌سازی این سوال استفاده کرد.

برای حل این سوال از دستورات زیر که در پوشهٔ مربوط به کدها نیز آمده است استفاده می‌کنیم:

```
% Autoassociative network for digit recognition using Hebbian learning
clc;
clear all;
close all;

%% load training images(5x7 px)
M=7; N=5;
P=zeros(M*N,10);
for n=0:9
    s=num2str(n);
    RGB=imread(s,'png');
    m=n+1;
    P(:,m)=reshape(rgb2gray(RGB),[M*N,1]); %column prototype vector
end
P = P/255*2-1; %normalizes data to be either -1 or 1

%% compute weight matrix using Hebb rule
W=zeros(M*N,M*N);
for n=1:10
    W=W+P(:,n)*P(:,n)';
```

```
end

% simple Hebb rule did not make it recognize images well
% try again using pseudoinverse
T=P;
W1=T*pinv(P);

%% test out network with training images
for n = 10:-1:1
    a=hardlims(W*P(:,n));
    outputImg=reshape(a,[M,N]);
    figure;
    imshow(outputImg,'InitialMagnification','Fit')
end

%% test out network with noisy inputs
P_noisy = P + randi([-1,1],M*N,10);

for n = 10:-1:1
    outputImg1=reshape(P_noisy(:,n),[M,N]);
    figure;
    subplot(1,2,1)
    imshow(outputImg1,'InitialMagnification','Fit')
    title('noisy image (Hebb)')

    subplot(1,2,2)
    a=hardlims(W*P_noisy(:,n));
    outputImg2=reshape(a,[M,N]);
    imshow(outputImg2,'InitialMagnification','Fit')
    title('reconstructed image (Hebb)')
end

for n = 10:-1:1
    outputImg1=reshape(P_noisy(:,n),[M,N]);
    figure;
```

```
    subplot(1,2,1)
    imshow(outputImg1,'InitialMagnification','Fit')
    title('noisy image (Pseudoinverse)')

    subplot(1,2,2)
    a=hardlims(W1*P_noisy(:,n));
    outputImg2=reshape(a,[M,N]);
    imshow(outputImg2,'InitialMagnification','Fit')
    title('reconstructed image (Pseudoinverse)')
end

%% test out network with parts of image missing
P_partial=P;
P_partial(8:17,:)=1;

for n = 10:-1:1
    outputImg1=reshape(P_partial(:,n),[M,N]);
    figure;
    subplot(1,2,1)
    imshow(outputImg1,'InitialMagnification','Fit')
    title('partial image (Hebb)')

    subplot(1,2,2)
    a=hardlims(W*P_partial(:,n));
    outputImg2=reshape(a,[M,N]);
    imshow(outputImg2,'InitialMagnification','Fit')
    title('reconstructed image (Hebb)')
end

P_partial=P;
P_partial(8:17,:)=1;

for n = 10:-1:1
    outputImg1=reshape(P_partial(:,n),[M,N]);
    figure;
```

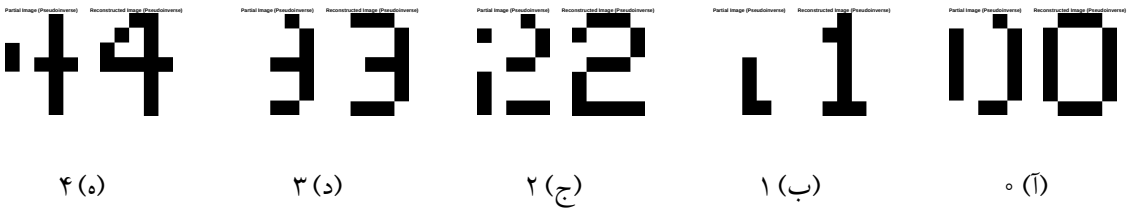
```
    subplot(1,2,1)
    imshow(outputImg1,'InitialMagnification','Fit')
    title('partial image (Pseudoinverse)')

    subplot(1,2,2)
    a=hardlims(W1*P_partial(:,n));
    outputImg2=reshape(a,[M,N]);
    imshow(outputImg2,'InitialMagnification','Fit')
    title('reconstructed image (Pseudoinverse)')
end
```

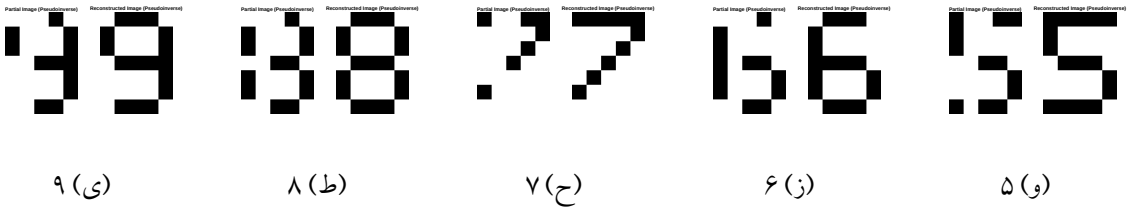
تابع hardlims هم که در کد اصلی بالا تعریف شده است به‌صورت زیر تعریف می‌گردد:

```
function [ a ] = hardlims( n )
%   hardlims Symmetric Hard Limit transfer function
%   Accepts column vector. Returns column vector.
%   behaves like unit step of amplitude 2 and vertical offset of -1
%   a = -1 for n < 0
%   a =  1 for n >= 0
    dims = size(n);
    a = zeros(dims);
    for i = 1:dims(1)
        for j = 1:dims(2)
            if n(i,j) < 0
                a(i,j) = -1;
            else
                a(i,j) = 1;
            end
        end
    end
end
```

با اجرای این دستورات نتایج به صورتی که در ادامه آورده شده است خواهد بود:

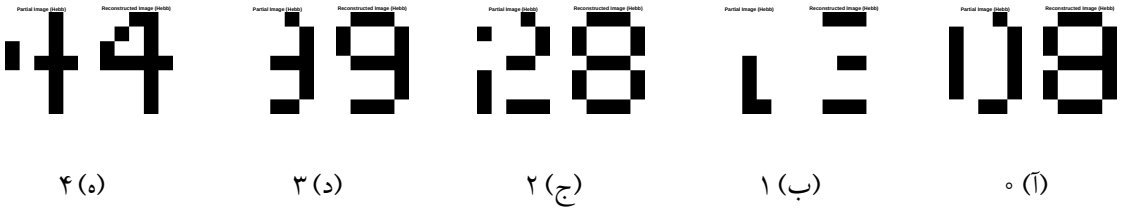


۰ (آ)　۱ (ب)　۲ (ج)　۳ (د)　۴ (ه)

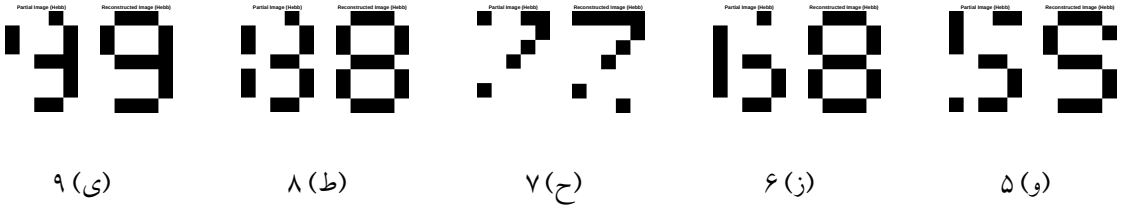


۵ (و)　۶ (ز)　۷ (ح)　۸ (ط)　۹ (ی)

شکل ۱: بازسازی اعداد از روی قسمتی از آن‌ها (Pseudoinverse).

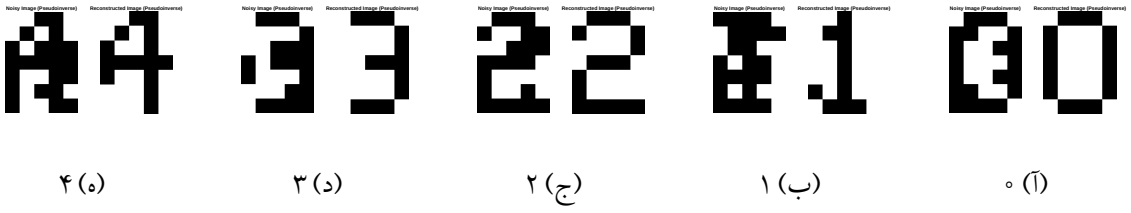


۰ (آ)　۱ (ب)　۲ (ج)　۳ (د)　۴ (ه)

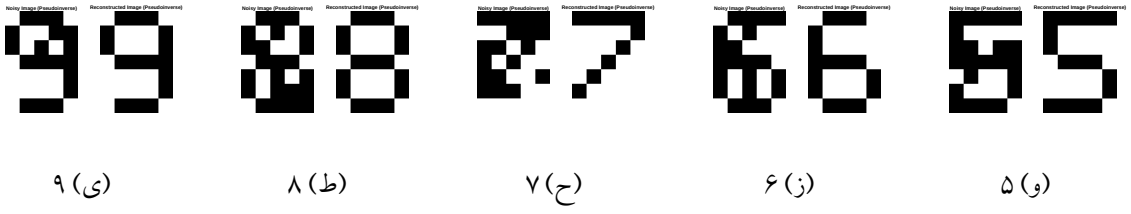


۵ (و)　۶ (ز)　۷ (ح)　۸ (ط)　۹ (ی)

شکل ۲: بازسازی اعداد از روی قسمتی از آن‌ها (Hebb).

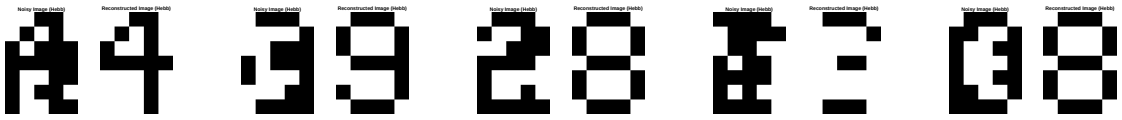


۰ (آ)　۱ (ب)　۲ (ج)　۳ (د)　۴ (ه)

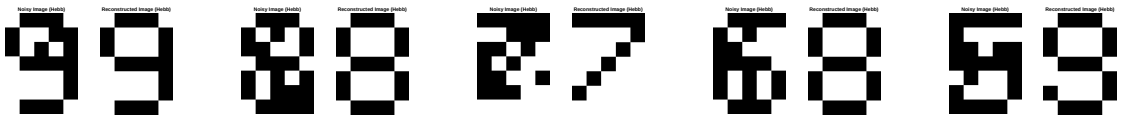


۵ (و)　۶ (ز)　۷ (ح)　۸ (ط)　۹ (ی)

شکل ۳: بازسازی اعداد از روی نویزی‌شدهٔ آن‌ها (Pseudoinverse).



۰ (آ)　　۱ (ب)　　۲ (ج)　　۳ (د)　　۴ (ه)



۵ (و)　　۶ (ز)　　۷ (ح)　　۸ (ط)　　۹ (ی)

شکل ۴: بازسازی اعداد از روی نویزی‌شدهٔ آن‌ها (Hebb).

پیوست

کدمنبع nnd7sh هم به‌صورت زیر تعریف می‌گردد:

```
function nnd7sh(cmd,arg1,arg2,arg3)
%NND7SH Supervised Hebb demonstration.

% Copyright 1994-2002 PWS Publishing Company and The MathWorks, Inc.
% $Revision: 1.6 $

%======================================================================

% CONSTANTS
me = 'nnd7sh';
p_x = 5; % pattern horizontal size
p_y = 6; % pattern vertical size

% DEFAULTS
if nargin == 0, cmd = ''; else cmd = lower(cmd); end

% FIND WINDOW IF IT EXISTS
fig = nndfgflg(me);
if length(get(fig,'children')) == 0, fig = 0; end

% GET WINDOW DATA IF IT EXISTS
if fig
  H = get(fig,'userdata');
  fig_axis = H(1);            % window axis
  desc_text = H(2);           % handle to first line of text sequence
```

```
  pattern = H(3:5);           % pattern axes 1-3
  tp_axis = H(6);             % test pattern
  rp_axis = H(7);             % response pattern
  P_ptr = H(8);               % handle to pattern matrix P
  p_ptr = H(9);               % handle to test pattern
  w_ptr = H(10);              % handle to weight matrix W
  rule1 = H(11);              % handle to first radio button
  rule2 = H(12);              % handle to second radio button
end

%=========================================================================
% Activate the window.
%
% ME() or ME('')
%=========================================================================

if strcmp(cmd,'')
  if fig
    figure(fig)
    set(fig,'visible','on')
  else
    feval(me,'init')
  end

%=========================================================================
% Close the window.
%
% ME() or ME('')
%=========================================================================

elseif strcmp(cmd,'close') & (fig)
  delete(fig)

%=========================================================================
% Initialize the window.
```

```
%
% ME('init')
%=====================================================================

elseif strcmp(cmd,'init') & (~fig)

  % STANDARD DEMO FIGURE
  fig = nndemof2(me,'DESIGN','Supervised Hebb','','Chapter 7');
  set(fig, ...
    'windowbuttondownfcn',nncallbk(me,'down'), ...
    'BackingStore','off',...
    'nextplot','add');
  H = get(fig,'userdata');
  fig_axis = H(1);
  desc_text = H(2);

  % ICON
  nndicon(7,458,363,'shadow')

  % ORIGONAL PATTERNS
  p1 = [0 1 1 1 1 0 ...
        1 0 0 0 0 1 ...
        1 0 0 0 0 1 ...
        1 0 0 0 0 1 ...
        0 1 1 1 1 0]';
  p2 = [0 0 0 0 0 0 ...
        1 0 0 0 0 0 ...
        1 1 1 1 1 1 ...
        0 0 0 0 0 0 ...
        0 0 0 0 0 0]';
  p3 = [1 0 0 0 0 0 ...
        1 0 0 1 1 1 ...
        1 0 0 1 0 1 ...
        1 0 0 1 0 1  ...
        0 1 1 0 0 1]';
```

```
P = [p1 p2 p3]*2-1;
p  = p1*2-1;

% WEIGHTS & OUTPUTS
w = P*P';
a = w*p;

% PATTERN AXES
pattern = zeros(1,5);
ltyell = nnltyell;
for k=1:5
  if k < 4
    title = sprintf('Pattern %g',k);
    pos = [25+115*(k-1) 230 100 100];
    pp = reshape(P(:,k),p_y,p_x);
    color = nngreen;
  elseif k == 4
    title = 'Test Pattern';
    pos = [25 20 160 160];
    pp = reshape(p,p_y,p_x);
    color = nndkgray;
  else
    title = 'Response Pattern';
    pos = [195 20 160 160];
    pp = reshape(a,p_y,p_x);
    color = nnred;
  end
  pattern(k) = nnsfo('a2',title,'','');
  set(pattern(k), ...
    'units','points',...
    'position',pos,...
    'color',nnltyell,...
    'xlim',[0 p_x], ...
    'ylim',[0 p_y],...
    'ydir','reverse')
```

```
    axis('off')
    pattern_h = zeros(p_y,p_x);
    box_x = [0 1 1 0 0];
    box_y = [0 0 1 1 0];
    for i=1:p_x, for j=1:p_y
      if pp(j,i) >= 0
        pattern_h(i,j) = fill(box_x+i-1,box_y+j-1,color,...
          'edgecolor',nndkblue,...
          'erasemode','none');
      else
        pattern_h(i,j) = fill(box_x+i-1,box_y+j-1,ltyell,...
          'edgecolor',nndkblue,...
          'erasemode','none');
      end
    end, end
    set(pattern(k),'userdata',pattern_h);
  end

  % WEIGHT RULE BUTTONS
  drawnow   % Let everything else appear before buttons
  rule1 = uicontrol(...
    'units','points',...
    'position',[395 190 70 20],...
    'style','radio',...
    'string','Hebb',...
    'backg',nnltgray,...
    'callback',[me '(''rule'',1)'],...
    'value',1);
  rule2 = uicontrol(...
    'units','points',...
    'position',[395 170 90 20],...
    'style','radio',...
    'string','Psuedoinverse',...
    'backg',nnltgray,...
    'max',[2],...
```

```
    'callback',[me '(''rule'',2)']);

  % BUTTONS
  if (exist('hintonw'))
    uicontrol(...
      'units','points',...
      'position',[410 140 60 20],...
      'string','Weights',...
      'callback',[me '(''weights'')'])
  end
  uicontrol(...
    'units','points',...
    'position',[410 110 60 20],...
    'string','Contents',...
    'callback','nndtoc')
  uicontrol(...
    'units','points',...
    'position',[410 80 60 20],...
    'string','Close',...
    'callback','delete(gcf)')

  % DATA POINTERS
  P_ptr = nnsfo('data'); set(P_ptr,'userdata',P);
  p_ptr = nnsfo('data'); set(p_ptr,'userdata',p);
  w_ptr = nnsfo('data'); set(w_ptr,'userdata',w);

  % SAVE WINDOW DATA AND LOCK
  H = [fig_axis desc_text pattern P_ptr p_ptr w_ptr rule1 rule2];
  set(fig,'userdata',H,'nextplot','new','color',nnltgray)

  % INSTRUCTION TEXT
  feval(me,'instr');

  nnchkfs;

```

```
%====================================================================
% Display the instructions.
%
% ME('instr')
%====================================================================

elseif strcmp(cmd,'instr') & (fig)
  nnsettxt(desc_text,...
    'Click on the green',...
    'grids to define target.',...
    'patterns. Click on the',...
    'gray grid to define',...
    'a test pattern.',...
    '',...
    'Select the rule to',...
    'calculate the network',...
    'weights below:')

%====================================================================
% Show weights.
%
% ME('weights')
%====================================================================

elseif strcmp(cmd,'weights') & (fig) & (nargin == 1)

  % GET DATA
  w = get(w_ptr,'userdata');

  f = figure;
  feval('hintonw',w);
  axis('equal');
  set(f,'name','Network Weights')
  t = get(gca,'title');
  set(t,'string','Green = Positive, Red = Negative')
```

```
236
237 %====================================================================
238 % Respond to mouse down.
239 %
240 % ME('down')
241 %====================================================================
242
243 elseif strcmp(cmd,'down') & (fig) & (nargin == 1)
244
245   set(fig,'nextplot','add')
246   for i=1:3
247     [in,x,y] = nnaxclik(pattern(i));
248     if in
249       feval(me,'down',x,y,i);
250       break
251     end
252   end
253   [in,x,y] = nnaxclik(tp_axis);
254   if in
255     feval(me,'down',x,y);
256   end
257   set(fig,'nextplot','new')
258
259 %====================================================================
260 % Respond to mouse down in pattern 1-3.
261 %
262 % ME('down',x,y,i)
263 %====================================================================
264
265 elseif strcmp(cmd,'down') & (fig) & (nargin == 4)
266
267   % GET DATA
268   x = floor(arg1)+1;
269   y = floor(arg2)+1;
270   i = arg3;
```

```
  green = nngreen;
  ltyell = nnltyell;
  red = nnred;
  P = get(P_ptr,'userdata');
  p = get(p_ptr,'userdata');
  squares = get(pattern(i),'userdata');
  rp_squares = get(rp_axis,'userdata');
  rule = get(rule2,'value')+1;

  % TOGGLE SQUARE
  ind = (x-1)*p_y+y;
  P(ind,i) = -P(ind,i);
  if P(ind,i) > 0
    set(squares(x,y),'facecolor',green);
  else
    set(squares(x,y),'facecolor',ltyell);
  end
  drawnow

  % UPDATE WEIGHTS
  if rule == 1
    w = P*P';
  else
    w = P*inv(P'*P)*P';
  end

  % STORE DATA
  set(P_ptr,'userdata',P);
  set(w_ptr,'userdata',w);

  % UPDATE OUTPUTS
  feval(me,'update')

%=======================================================================
% Respond to mouse down in test pattern.
```

```
%
% ME('down',x,y)
%=====================================================================

elseif strcmp(cmd,'down') & (fig) & (nargin == 3)

  % GET DATA
  x = floor(arg1)+1;
  y = floor(arg2)+1;
  dkgray = nndkgray;
  ltyell = nnltyell;
  tp_squares = get(tp_axis,'userdata');
  rp_squares = get(rp_axis,'userdata');
  p = get(p_ptr,'userdata');
  w = get(w_ptr,'userdata');

  % TOGGLE SQUARE
  ind = (x-1)*p_y+y;
  p(ind) = -p(ind);
  if p(ind) > 0
    set(tp_squares(x,y),'facecolor',dkgray);
  else
    set(tp_squares(x,y),'facecolor',ltyell);
  end
  drawnow

  % STORE DATA
  set(p_ptr,'userdata',p);

  % UPDATE OUTPUTS
  feval(me,'update')

%=====================================================================
% Set weight rule.
%
```

```
% ME('rule',i)
%=============================================================

elseif strcmp(cmd,'rule') & (fig) & (nargin == 2)

  % SET RADIO BUTTONS
  if arg1 == 1
    set(rule1,'value',1)
    set(rule2,'value',0)
  else
    set(rule1,'value',0)
    set(rule2,'value',2)
  end

  % GET DATA
  P = get(P_ptr,'userdata');

  % UPDATE WEIGHTS
  if arg1 == 1
    w = P*P';
  else
    w = P*inv(P'*P)*P';
  end

  % STORE DATA
  set(w_ptr,'userdata',w)

  % UPDATE OUTPUTS
  feval(me,'update')

%=============================================================
% Update response pattern.
%
% ME('update')
%=============================================================
```

```
376
377 elseif strcmp(cmd,'update') & (fig)
378
379   % GET DATA
380   red = nnred;
381   ltyell = nnltyell;
382   p = get(p_ptr,'userdata');
383   w = get(w_ptr,'userdata');
384   rp_squares = get(rp_axis,'userdata');
385
386   % UPDATE OUTPUTS
387   a = w*p;
388   a = reshape(a,p_y,p_x);
389   for i=1:p_x, for j=1:p_y
390     if a(j,i) > 0
391       set(rp_squares(i,j),'facecolor',red)
392     else
393       set(rp_squares(i,j),'facecolor',ltyell)
394     end
395   end, end
396
397 %=======================================================================
398 end
```