%% CMPT340 - Activity 7: Kidney PCA

%

% \*Goal\*

% In this assignment, we will apply PCA on 3D point clouds of kidneys.

% This will allow us to create a model that learns how kidneys deform.

% We will be able to manipulate this model and it will deform based on the

% variations found in our dataset.

%

%

% \*Data files\*

% The data files are under the folder ./kidneys\_3d\_points:

% The folder contains sets of 3D points for 20 kidneys.

%

% \*Instructions\*

% The questions and specific instructions are given below. We have included

% some "checks" with answers to allow you to see if certain parts of your

% code corresponds to what we expect. If you have the same answers,

% this should help confirm that you are on the right track.

%

% Some of the instructions are not specific questions, but are there

% to help guide you through the work.

%

% Whenever you see:

%

% %--------- Your Code Here ------%

%

% %-------------------------------%

%

% You should enter your code in that area.

%

% You don't have to submit anything for this activity. The solution key

% will be posted afterwards.

%

%

% \*Save your results\*

% please save your results as .gif under the folder ./html

% you should still be able to visualize your results using generic image viewer

% after closing MATLAB

% Clean up

clear all; close all;

clc

if ~exist('html')

mkdir('html')

end

%% Q. Load and display the sample data

% Load the file "DeformedObject (13).mat" into variable K13.

% Use plot3 to plot all the point as small dots.

% Do not connect the dots together.

%--------- Your Code Here ------%

K13 = load('kidneys\_3d\_points/DeformedObject (13).mat').DeformedObject;

plot3(K13(:,1), K13(:,2), K13(:,3),'.');

%-------------------------------%

% \*\*\* check \*\*\*

display(sprintf('Load data check (size): %i', isequal(size(K13),[1924,3])));

display(sprintf('Load data check (coordinate): %i', round(K13(1924,1))==41));

% Find how many 3D points (landmarks) there are.

% Save the answer in variable L

%--------- Your Code Here ------%

L = size(K13,1)

%-------------------------------%

display(sprintf('Num Landmark check: %i',L == 1924))

%% Q. Create observation matrix

% Convert K13 into a single column observation by stacking the x coordinates,

% the y coordinates, then the z coordinates all below each other

%--------- Your Code Here ------%

K13 = vertcat(K13(:,1), K13(:,2), K13(:,3))

size(K13)

%-------------------------------%

% \*\*\* check \*\*\*

display(sprintf('K13 column check (size): %i', isequal(size(K13),[5772,1])))

display(sprintf('K13 column check (value): %i', round(K13(5769))==16))

%%

%% Q. Load all data files and save all the data into an observation matrix X

% the resulting X should have:

% number of rows = number of observations (i.e. number of kidneys);

%

% number of columns = number of 3D points per kidney \* 3 (we multiply by 3

% as each point has x,y and z coordinates);

%

%

%--------- Your Code Here ------%

path = fullfile(pwd,'kidneys\_3d\_points');

numObservations = 20;

for i = 1:numObservations

inputFile = load(fullfile(path, ['DeformedObject (', sprintf('%i',i), ').mat'])).DeformedObject;

vertInput = vertcat(inputFile(:,1), inputFile(:,2), inputFile(:,3));

for j = 1:(1924\*3)

X(i,j) = vertInput(j);

end

end

%-------------------------------%

% \*\*\* check \*\*\*

display(sprintf('X size:%i',isequal(size(X),[20,5772])));

% check some sample coordinates

display(sprintf('X values:%i', isequal(round(X(10,20)),43)));

display(sprintf('X values:%i', isequal(round(X(19,4000)),66)));

%% Q. Plot all data

% Write a for loop that will display, one at a time, all kidneys using plot3

% Create a GIF of each kidney and export the figures under the html folder.

fAllData = figure(1);

%--------- Your Code Here ------%

filename = 'kidneys.gif';

for i = 1:numObservations

plot3(X(i,(1:1924)), X(i,(1925:3848)), X(i,(3849:5772)),'.');

%%%%%%% Referenced from https://www.mathworks.com/matlabcentral/answers/94495-how-can-i-create-animated-gif-images-in-matlab

%%%%%%% and from the GIF code below

filename = fullfile('html','kidney.gif');

frame = getframe(fAllData);

im = frame2im(frame);

[imind,cm] = rgb2ind(im,256);

if i == 1

imwrite(imind,cm,filename,'gif','Loopcount',inf);

else

imwrite(imind,cm,filename,'gif','WriteMode','append');

end

%%%%%%%

end

%-------------------------------%

close(fAllData)

%%

%% Q. The mean kidney

% Calculate and plot the "mean kidney" shape.

% The mean kidney is the kidney produced by taking the mean of all the

% kidney data. It should look like an "average" kidney.

%--------- Your Code Here ------%

mn = mean(X)';

plot3(mn(1:1924), mn(1925:3848), mn(3849:5772),'.');

%-------------------------------%

% \*\*\* check \*\*\*

display(sprintf('mean size check: %i', isequal(size(mn), [5772,1])));

% random check

display(sprintf('mean val check: %i', isequal(round(mn(1000:1005))', [ 51 54 53 58 56 62])));

%% Q. Apply PCA

% Perform PCA using the \_pca()\_ command. Make sure to compute the eigenvectors,

% scores, and eigenvalues.

% note that PCA sorts output eigenvalue magnitudes in decreading order

%--------- Your Code Here ------%

[eigenvectors,score,eigenvalues] = pca(X);

%-------------------------------%

%% Q. Extract PC1

% Extract the eigenvector with the largest eigenvalue and save it in

% a column variable PC1

%--------- Your Code Here ------%

PC1 = eigenvectors(:,1);

%-------------------------------%

display(sprintf('PC1 check:%i',isequal(round((PC1(100,1))\*10^7),1444)));

%% Q. Create a new shape along PC1

% Create a new shape Xn by moving one \*unit\* along PC1 away

% from the mean. Represent Xn as a column vector.

%--------- Your Code Here ------%

Xn = PC1 + mn;

v1 = eigenvalues(1);

%-------------------------------%

display(sprintf('PC1 shape check:%i', isequal(round(Xn(200:205,1)'), [59 35 39 55 32 55])));

%% Q. Plot the shape from PC1

% Plot this new shape \_Xn\_ in 3D.

% Hint: This should look somewhat like a kidney still.

figure(2)

%--------- Your Code Here ------%

plot3(Xn(1:1924), Xn(1925:3848), Xn(3849:5772),'.');

%-------------------------------%

%% Q. Extract PC2

% Extract the eigenvector with the 2nd largest eigenvalue and save it

% in a column variable PC2 AND save its corresponding eigenvalue in variable l2

%--------- Your Code Here ------%

PC2 = eigenvectors(:,2);

v2 = eigenvalues(2);

%-------------------------------%

display(sprintf('PC2 check:%i', isequal(round(PC2(2000:2005,1)'\*10^7), [-26968 -18511 -21273 -28805 -24438 -26308])));

display(sprintf('v2 check:%i', isequal(round(v2), 3113)));

%% Q. Create and plot the PC2 shape

% Create a new shape (also Xn) by moving 3 standard deviations along PC2

% away from the mean. Note that the eigenvector should be \*appropriately\*

% weighted by it's correpsonding eigenvalue.

% Hint: This should look like a kidney.

%--------- Your Code Here ------%

Xn = 3\*sqrt(v2) \* PC2 + mn;

%-------------------------------%

% plot the shape in 3D

figure(3)

%--------- Your Code Here ------%

plot3(Xn(1:1924), Xn(1925:3848), Xn(3849:5772),'.');

%-------------------------------%

display(sprintf('PC2 shape: %i', isequal(round(Xn(1:5))', [46 43 45 45 52])));

%% Q. Moving along the first 3 PCs to generate new kidneys

% Plot the shape changes as the PCs are varied independently

% Write a loop that shows how the kidney changes when a single principal

% component (PC) is changed and the rest are fixed.

%

% We will only change the first 3 PCs.

%

% We will only allow the kidneys to change between -500 and +500 standard deviations

% so we get deformations that could be clearly visualized.

%

% We will also plot them so all appear in the same figure.

%

% Create a GIF and make sure it is saved under the html folder along with

% other figures

% Create our figure.

hFig = figure(4);

% Make it a bit larger so we can see the kidneys better. You might need to

% adjust this based on your screen size.

set(hFig, 'Position', [50 50 1500 400])

% Loop from -5 to +5 standard deviations, where we change by 0.1 standard

% deviation in each iteration.

for k=5:5

% Change PC1 goes here...

subplot(1,3,1);

%--------- Your Code Here ------%

Xn1 = k\*sqrt(v1) \* PC1 + mn;

plot3(Xn1(1:1924), Xn1(1925:3848), Xn1(3849:5772),'.');

%-------------------------------%

% We add a title so we can see the standard deviation change.

title(sprintf('PC1: %.3f', k));

axis([0 100 0 150 0 100])

axis image;

% Change PC2

subplot(1,3,2);

%--------- Your Code Here ------%

Xn2 = k\*sqrt(v2) \* PC2 + mn;

plot3(Xn2(1:1924), Xn2(1925:3848), Xn2(3849:5772),'.');

%-------------------------------%

title(sprintf('PC2: %.3f', k));

%axis([0 100 0 150 0 100])

axis image

% Change PC3

subplot(1,3,3);

%--------- Your Code Here ------%

PC3 = eigenvectors(:,3);

v3 = eigenvalues(3);

Xn3 = k\*sqrt(v3) \* PC3 + mn;

plot3(Xn3(1:1924), Xn3(1925:3848), Xn3(3849:5772),'.');

%-------------------------------%

title(sprintf('PC3: %.3f', k));

%axis([0 100 0 150 0 100])

axis image;

drawnow;

%%%%%%% GIF code.

filename = fullfile('html','pcChange.gif');

frame = getframe(gcf);

im = frame2im(frame);

[imind,cm] = rgb2ind(im,256);

if k == -5

imwrite(imind,cm,filename,'gif','Loopcount',inf);

else

imwrite(imind,cm,filename,'gif','WriteMode','append');

end

%%%%%%%

pause(0.05)

end

% close(hFig);

%%

%% Q. Rough description of what happens when the PCs change

% Above we only changed 1 PC independently (fix the others, only change one)

% In words, give a brief description of how the kidney subtely changes as we change each PC.

% Hint: Examine/rotate each kidney at the end of the above loop, and see

% in what ways the kidneys differ.

% e.g. Does changing one PC stretch a specific part of the kidney?

% e.g. Does changing one PC cause the kidney to compress/expand?

pc1str = 'When PC1 increases, the kidney ';

%----- Your description here ------%

myPc1Description = ' ';

%----------------------------------%

display([pc1str, myPc1Description]);

pc2str = 'When PC2 increases, the kidney ';

%----- Your description here ------%

myPc2Description = '';

%----------------------------------%

display([pc2str, myPc2Description]);

pc3str = 'When PC3 increases, the kidney ';

%----- Your description here ------%

myPc3Description = '';

%----------------------------------%

display([pc3str, myPc3Description]);

%% Q. Come up with 3 interesting shapes

% Instead of changing 1 PC and fixing the rest, we can change the first 3 PCs at

% the same time. Come up with 3 interesting shapes where the first 3 PCs

% have different non-zero weightings.

%

% Deform between -500 and +500 standard deviations

% so we get deformations that could be clearly visualized.

%

% Put the standard deviations values that you used in the title.

figure(5);

%--------- Your Code Here ------%

pc1std = -500;

pc2std = -400;

pc3std = -300;

Xn4 = (-500 \* PC1)+(-400 \* PC2)+(-300 \* PC3) + mn;

plot3(Xn4(1:1924), Xn4(1925:3848), Xn4(3849:5772),'.');

%-------------------------------%

title(sprintf('PC1: %.2f, PC2: %.2f, PC3: %.2f', pc1std,pc2std,pc3std));

axis image;

%%

figure(6);

%--------- Your Code Here ------%

pc1std = 500

pc2std = 400

pc3std = 300

Xn5 = (500 \* PC1)+(400 \* PC2)+(300 \* PC3) + mn;

plot3(Xn5(1:1924), Xn5(1925:3848), Xn5(3849:5772),'.');

%-------------------------------%

title(sprintf('PC1: %.2f, PC2: %.2f, PC3: %.2f', pc1std,pc2std,pc3std));

axis image;

%%

figure(7);

%--------- Your Code Here ------%

pc1std = -500

pc2std = 100

pc3std = 500

Xn6 = (-500 \* PC1)+(100 \* PC2)+(500 \* PC3) + mn;

plot3(Xn6(1:1924), Xn6(1925:3848), Xn6(3849:5772),'.');

%-------------------------------%

title(sprintf('PC1: %.2f, PC2: %.2f, PC3: %.2f', pc1std,pc2std,pc3std));

axis image;

%%