Javier Palomares Homework 1 a

Programming Questions

In [1]:
```
import numpy as np
```

Question 1

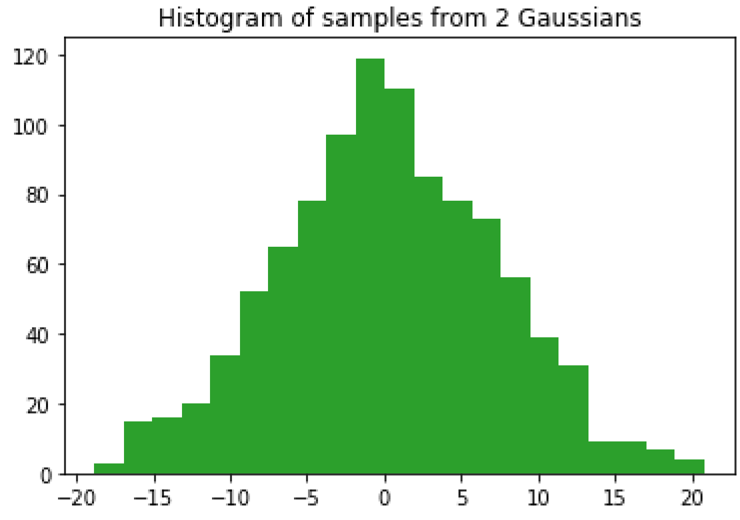
Create 1000 samples from a Gaussian distribution with mean -10 and standard deviation 5. Create another 1000 samples from another independent Gaussian with mean 10 and standard deviation 5.

In [2]:
```
numSamples = 1000
mean1 = -10
stdDev1 = 5
samples1 = np.random.normal(mean1,stdDev1,numSamples)
mean2 = 10
stDev2 = 5
samples2 = np.random.normal(mean2,stDev2,numSamples)
```

Part a

Take the sum of 2 these Gaussians by adding the two sets of 1000 points, point by point, and plot the histogram of the resulting 1000 points. What do you observe?

In [14]:
```
samplesSum = samples1+samples2
import matplotlib.pyplot as plt
plt.hist(samplesSum, bins='auto')
plt.title('Histogram of samples from 2 Gaussians')
plt.show()
```



I observed a Gaussian distribution centered around 0. It also looks like the standard deviation is greater than 5.

Part b

Estimate the mean and the variance of the sum

I estimate the mean is 0, and the variance is around 7^2. I estimated this visually from the histogram

In [105]:

```
print('The mean is {}'.format(np.mean(samplesSum)))
print('The variance is {}'.format(np.var(samplesSum)))
```

```
The mean is 0.2581822261091743
The variance is 50.48010707953012
```

Question 2: Central Limit Theorem

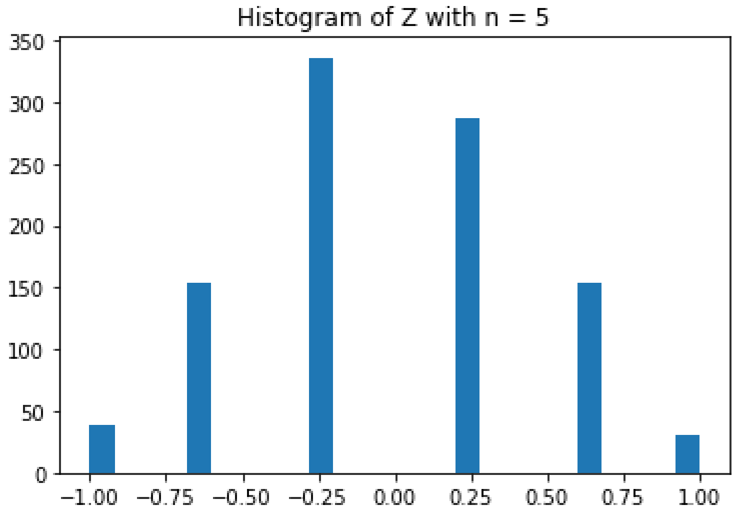
Let Xi be an iid Bernoulli random variable with value {-1,1}. Look at the random variable Zn = 1 nPXi. By taking 1000 draws from Zn, plot its histogram.Check that for small n (say, 5-10) Zn does not look that much like a Gaussian, but when n is bigger (already by the time n = 30 or 50) it looks much more like a Gaussian. Check also for much bigger n: n = 250, to see that at this point, one can really see the bell curve.

Small n

In [195]:

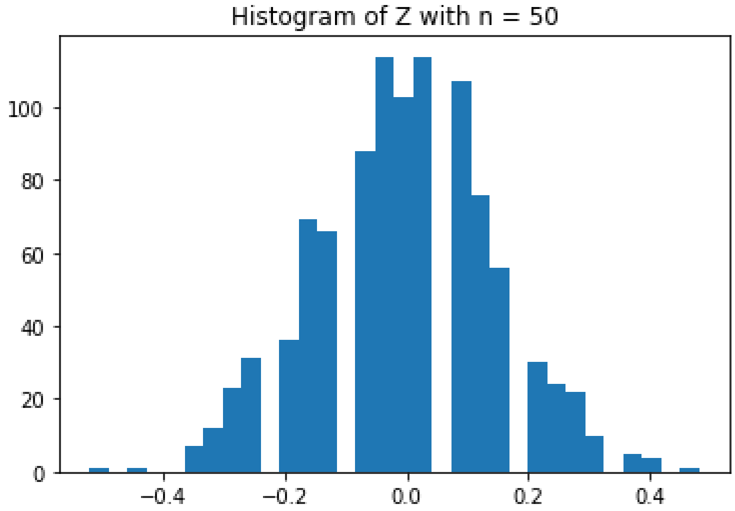
```
def replaceInArray(arr,toReplace,replaceWith):
    for i in range(len(arr)):
        if(arr[i] == toReplace):
            arr[i] = replaceWith

numTrials = 1000
z = np.zeros(numTrials)
n = 5
p = .5
for i in range(numTrials):
    x=np.random.binomial(size=n, n=1, p=p)
    replaceInArray(x,0,-1)
    z[i] = 1/n * np.sum(x)
plt.hist(z, bins='auto')
plt.title('Histogram of Z with n = 5')
plt.show()
```



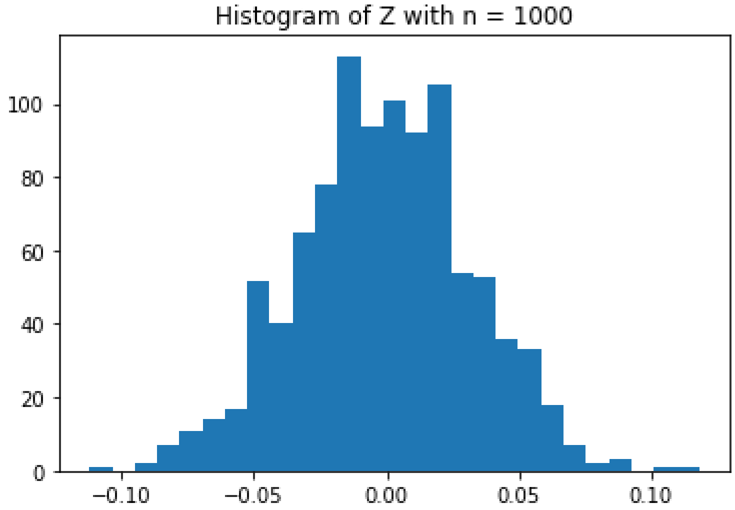
In [196]:

```
z = np.zeros(numTrials)
n = 50
p = .5
for i in range(numTrials):
    x=np.random.binomial(size=n, n=1, p=p)
    replaceInArray(x,0,-1)
    z[i] = 1/n * np.sum(x)
plt.hist(z, bins='auto')
plt.title('Histogram of Z with n = 50')
plt.show()
```



In [203]:

```
z = np.zeros(numTrials)
n = 1000
p = .5
for i in range(numTrials):
    x=np.random.binomial(size=n, n=1, p=p)
    replaceInArray(x,0,-1)
    z[i] = 1/n * np.sum(x)
plt.hist(z, bins='auto')
plt.title('Histogram of Z with n = 1000')
plt.show()
```



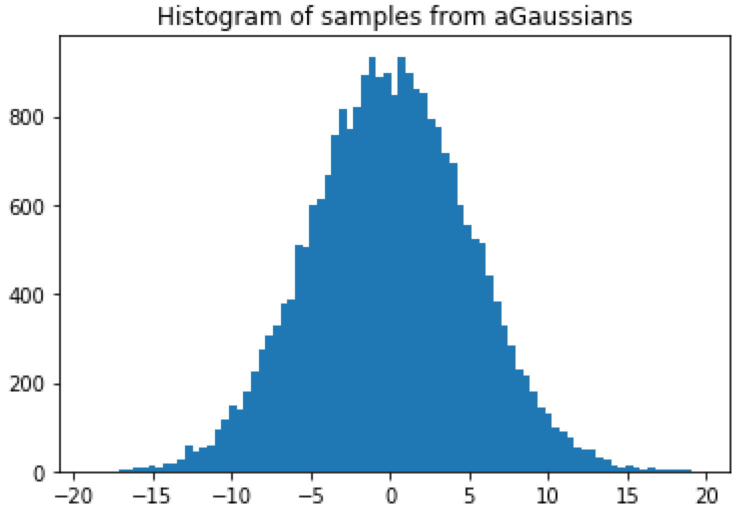
The histogram looks more like a Gaussian with n=1000

Question 3

Estimate the mean and standard deviation from 1 dimensional data: generate 25,000 samples from a Gaussian distribution with mean 0 and standard deviation 5. Then estimate the mean and standard deviation of this gaussian using elementary numpy commands, i.e., addition, multiplication, division (do not use a command that takes data and returns the mean or standard deviation).

In [106]:

```
numSamples = 25000
mean = 0
stdDev = 5
samples = np.random.normal(mean,stdDev,numSamples)
plt.hist(samples, bins='auto')
plt.title('Histogram of samples from aGaussians')
plt.show()
```



Visually, I estimate the mean is 0, and the stdDev is around 5.

Computing the mean and standard deviation from elemental operations, I found:

In [107]:

```
sum = 0
for i in range(numSamples):
    sum += samples[i]
mean = sum / numSamples

variance = 0
for i in range(numSamples):
    variance += (samples[i] - mean)**2
variance /= numSamples
```

In [108]:

```
print("The mean is {}".format(mean))
print("The standard deviation is {}".format(np.sqrt(variance)))
```

```
The mean is 0.016334245976241328
The standard deviation is 5.033722935531415
```

Question 4

Estimate the mean and covariance matrix for multi-dimensional data: generate 10,000 samples of 2 dimensional data from the Gaussian distribution. Then, estimate the mean and covariance matrix for this multi-dimensional data using elementary numpy commands, i.e., addition, multiplication, division (do not use a command that takes data and returns the mean or standard deviation).

In [111]:

```
numSamples = 10000
mean = [-5,5]
covarianceMatrix = [[20, .8], [.8, 30]]
samples = np.random.multivariate_normal(mean, covarianceMatrix, numSa
mples)
X = samples[:,0]
Y = samples[:,1]

#Covariance_x_y  E [ (X - E[x]]) (Y - E[Y]) ]
meanX = 0
meanY = 0
for i in range(numSamples):
    meanX += X[i]
    meanY += Y[i]
meanX /= numSamples
meanY /= numSamples

#Covariance_x_y  E [ (X - E[x]]) (Y - E[Y]) ]
def covXY(X,Y,meanX,meanY):
    numSamples = len(X)
    cov = 0
    for j in range(numSamples):
        cov += (X[j] - meanX)*(Y[j] - meanY)
    cov /= numSamples
    return cov


cov = [[covXY(X,X,meanX,meanY), covXY(X,Y,meanX,meanY)],
       [covXY(Y,X,meanY,meanX), covXY(Y,Y,meanY,meanY)]]
print("The mean of X is {}".format(meanX))
print("The mean of Y is {}".format(meanY))
print("The covariance matrix is")
print(np.matrix(cov))
```

```
The mean of X is -4.997486816532748
The mean of Y is 5.053318489738599
The covariance matrix is
[[ 20.18486288   0.8123284 ]
 [  0.8123284   30.10707126]]
```

Question 5

Download from Canvas/Files the dataset PatientData.csv. Each row is a patient and the last column is the condition that the patient has. Do data exploration using Pandas and other visualization tools to understand what you can about the dataset.

In [277]:

```
import pandas as pd
filepath='./PatientData.csv'
df = pd.read_csv(filepath,header=None)
df.info()
df.describe()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 452 entries, 0 to 451
Columns: 280 entries, 0 to 279
dtypes: float64(120), int64(155), object(5)
memory usage: 988.8+ KB
```

Out[277]:

	0	1	2	3	4	5	6	
count	452.000000	452.000000	452.000000	452.000000	452.000000	452.000000	452.000000	45
mean	46.471239	0.550885	166.188053	68.170354	88.920354	155.152655	367.207965	16
std	16.466631	0.497955	37.170340	16.590803	15.364394	44.842283	33.385421	3
min	0.000000	0.000000	105.000000	6.000000	55.000000	0.000000	232.000000	10
25%	36.000000	0.000000	160.000000	59.000000	80.000000	142.000000	350.000000	14
50%	47.000000	1.000000	164.000000	68.000000	86.000000	157.000000	367.000000	16
75%	58.000000	1.000000	170.000000	79.000000	94.000000	175.000000	384.000000	17
max	83.000000	1.000000	780.000000	176.000000	188.000000	524.000000	509.000000	38

8 rows × 275 columns

For example:
(a) How many patients and how many features are there?

In [144]:

```
numPatients= df.shape[0]
numFeatures = df.shape[1]
print("There are {} patients and {} feature".format(numPatients,numFe
atures))
```

```
There are 452 patients and 280 feature
```

b) What is the meaning of the first 4 features? See if you can understand what they mean.

In [140]:

```
feature1 = df.loc[:,0]
feature2 = df.loc[:,1]
feature3 = df.loc[:,2]
feature4 = df.loc[:,3]

# patient condition is the last column
patientCondition = df.loc[:,numFeatures-1]

print("feature1  type")
print(feature1.get_dtype_counts())

print("\nfeature2  type")
print(feature2.get_dtype_counts())

print("\nfeature3  type")
print(feature3.get_dtype_counts())

print("\nfeature4  type")
print(feature4.get_dtype_counts())
```

```
feature1  type
int64    1
dtype: int64

feature2  type
int64    1
dtype: int64

feature3  type
int64    1
dtype: int64

feature4  type
int64    1
dtype: int64
```

In [136]:

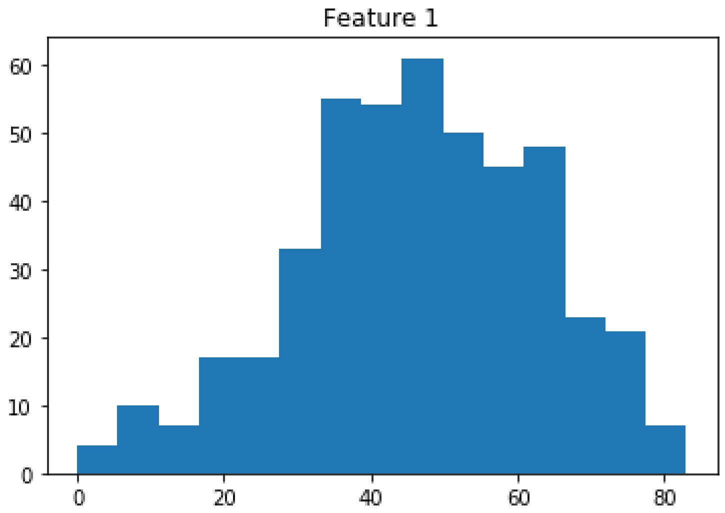
```
import matplotlib.pyplot as plt

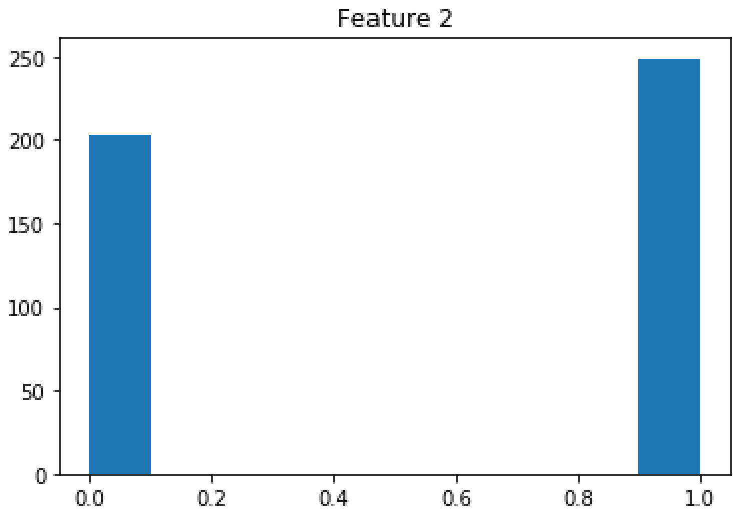
plt.hist(feature1, bins='auto')
plt.title('Feature 1')
plt.show()

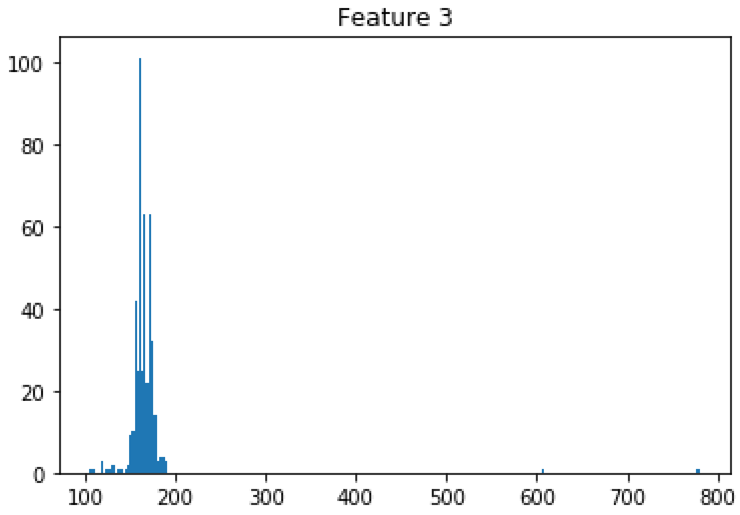
plt.hist(feature2,bins='auto')
plt.title('Feature 2')
plt.show()

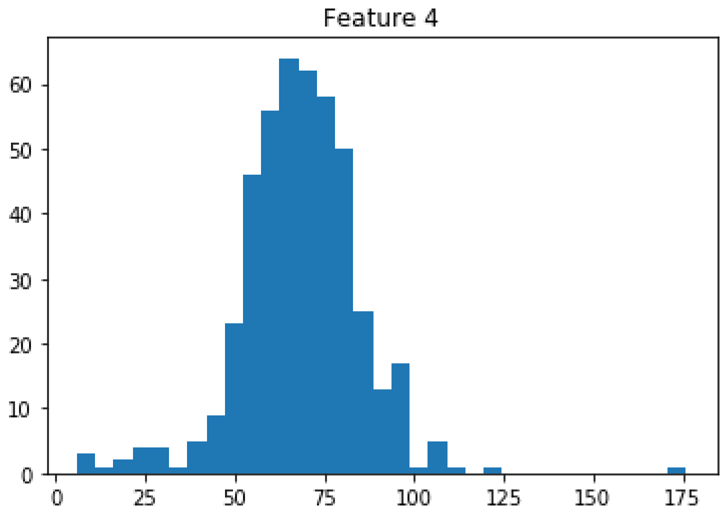
plt.hist(feature3,bins='auto')
plt.title('Feature 3')
plt.show()

plt.hist(feature4, bins='auto')
plt.title('Feature 4')
plt.show()
```


Feature 1
60
50
40
30
20
10
0
0
20
40
60
80


Feature 2
250
200
150
100
50
0
0.0
0.2
0.4
0.6
0.8
1.0


Feature 3
100
80
60
40
20
0
100
200
300
400
500
600
700
800



Looking at the range of values, it looks like

- first column is age in years,
- second column is a binary variable representing the gender
- third column is weight in pounds
- fourth column is height in inches

c) Are there missing values? Replace them with the average of the corresponding feature column

In [279]:

```
nanMatrix = ~df.applymap(np.isreal)
# find all the columns that have missing values
nanCols = nanMatrix.all(0)
for col in range(len(nanCols)):
    if(nanCols[col]):
        # the column has missing values.
        # replace them with the mean
        values = df.iloc[:,col]
        s = 0
        n = 0
        # find the mean of the column
        for row in range(len(values)):
            if str.isnumeric(values.iloc[row]):
                s += float(values.iloc[row])
                n += 1
        mean = s/n
        for row in range(len(values)):
            # replace numeric strings with their numeric value
            if str.isnumeric(values.iloc[row]):
                df.iloc[row,col] = float(values.iloc[row])
             # replace nans with the mean value
            else:
                df.iloc[row,col] = mean
df.info()
df.describe()
```

```
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8 rows × 275 columns

d) How could you test which features strongly influence the patient condition and which do not
I will test for strong influence by computing the covariance of each feature with the patientCondition

In [293]:

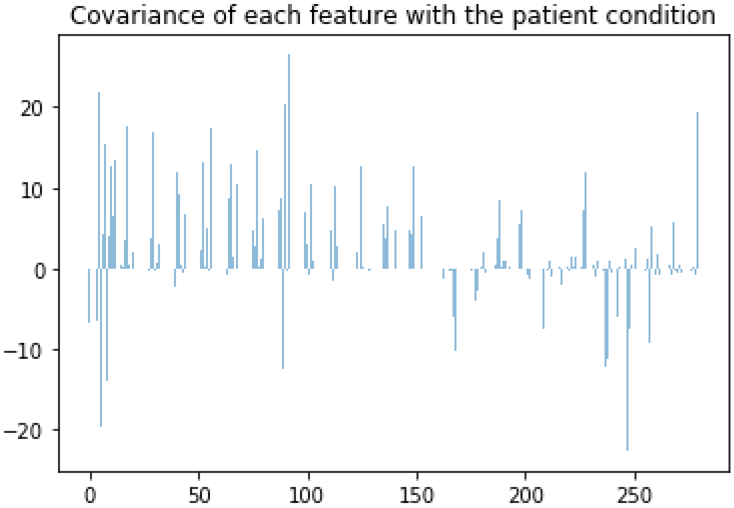
```
featureCovariance = np.zeros(numFeatures)
for i in range(len(featureCovariance)):
    feature = df.iloc[:,i]
    featureCovariance[i] = np.cov(feature.astype('float'),patientCondition)[0][1]
```

List what you think are the three most important features.

In [297]:

```
x = np.arange(len(featureCovariance))

plt.bar(x, featureCovariance, align='center', alpha=0.5)
plt.title('Covariance of each feature with the patient condition')
plt.show()
```



Covariance of each feature with the patient condition

In [302]:

```
np.argpartition(featureCovariance,-3)[-3:]
```

Out[302]:

```
array([90,  4, 92], dtype=int64)
```

The features with the highest covariance are in columns at position 90, 4, 92