Guassian Classifier (2D visualization)

In [14]:

```
# Importing necessary packages
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
plt.style.use(["science","no-latex"])
figsize_val = (8,8)
```

Guassian distribution for multi variables

$$\mathcal{N}(\mathbf{x}|\boldsymbol{\mu},\Sigma) \stackrel{\text{def}}{=} \frac{1}{(2\pi)^{p/2}|\Sigma|^{1/2}} \exp[-\tfrac{1}{2}(\mathbf{x}-\boldsymbol{\mu})^T\Sigma^{-1}(\mathbf{x}-\boldsymbol{\mu})]$$

In [15]:

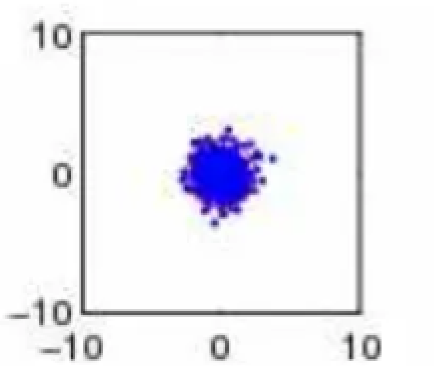
```
# Function to Apply normal distribution formula for a particular N
dimensional point
def norm_dis(x,mean,cov_mat,num_c):
    '''
    INPUTS:
        x is a vector representing the number of features
(dimensions) => numpy array
        mean is the mean of this particular distribution => float
        cov_mat is the covariance matrix => N-dimensional numpy array
        num_c is the number of dimensions => integer
    OUTPUT:
        returns the value of normal distribution at given x for the
corresponding mean and covariance
    '''
    den = (1/((2*np.pi)**(num_c/2))*(np.linalg.det(cov_mat)**(0.5)))
    exp_val = np.matmul(np.matmul(np.transpose(x-
mean),np.linalg.inv(cov_mat)),(x-mean))
    return den*(np.exp((-0.5)*exp_val))

# Function to Iterate over the points to get the overall distribution
def iter_norm_dis(x1,y1,num_c,cov_mat,mean):
    '''
    INPUT:
        x1,y1 are 2D values of range whose meshgrid is to be created
```

```
to evaluate the function
        at multiple points
        => numpy arrays
    OUTPUT:
        returns an N-dimensional (here 2 D mostly) with the values
from the norm_dist function
    '''
    [x1,y1] = np.meshgrid(x1,y1,indexing="ij")
    z = np.zeros((x1.shape[0],y1.shape[1]))

    # for each location, find the probability value and store it in z
    for i in range(x1.shape[0]):
        for j in range(y1.shape[1]):
            z[i][j] = norm_dis(np.array([x1[i][j],y1[i]
[j]]),mean,cov_mat,num_c)
    return (z,x1,y1)
```

In [16]:

```
# Configuring the number of classes (Currently works only for 2D)
number_of_classes = 2
mean = 0
```

Classes are uncorrelated and their auto-correlation values are same

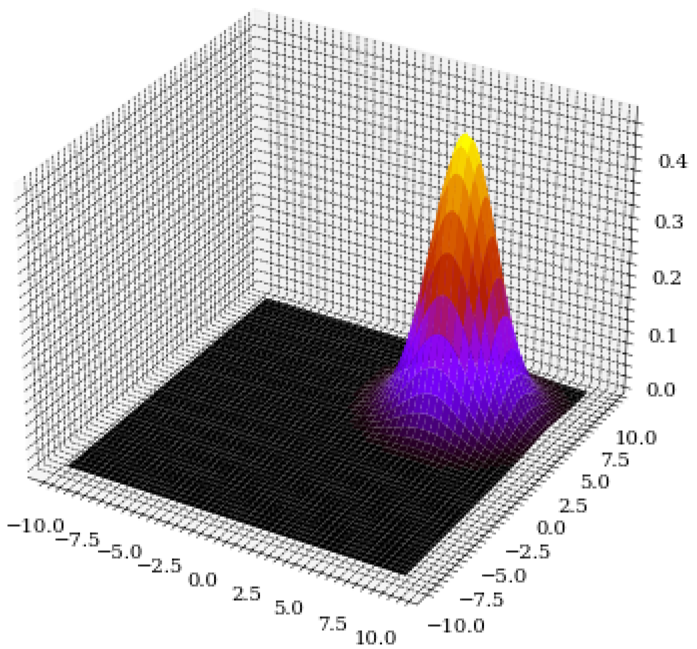


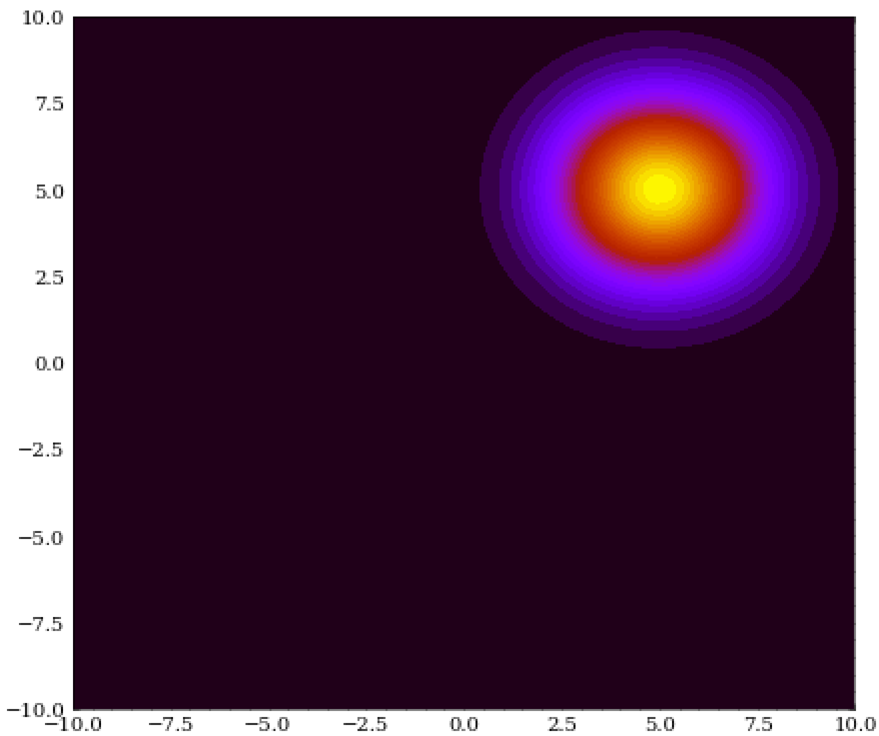
$$\Sigma = \begin{pmatrix} \sigma^2 & 0 \\ 0 & \sigma^2 \end{pmatrix}$$

In [49]:

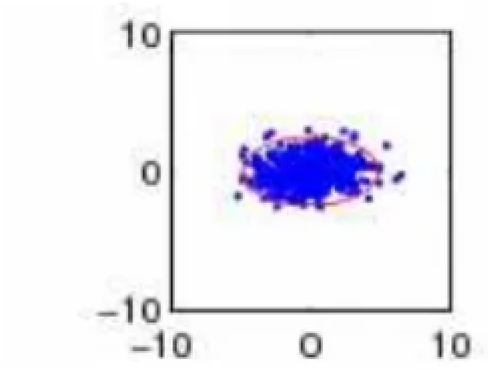
```
scaling_factor = 3
covar_matrix = scaling_factor*np.identity(number_of_classes)
```

```python
mean = 5
x1 = np.linspace(-10,10,100)
x2 = np.linspace(-10,10,100)

#print(norm_dis(np.array([xx1[i],yx2[j]]),mean,covar_matrix,number_of_c
#= 0.2584318220246485

fig = plt.figure(figsize=(7,14))
z,x,y = iter_norm_dis(x1,x2,number_of_classes,covar_matrix,mean)
ax = fig.add_subplot(2, 1, 1, projection='3d')
ax.plot_surface(x,y,z,cmap="gnuplot")
ax = fig.add_subplot(2, 1, 2)
ax.contourf(x,y,z,40,cmap="gnuplot")
# plt.Countor(x,y,z)
# for i in range(2):
#     ax[i].set_xlabel("X1")
#     ax[i].set_ylabel("X2")
#     ax[i].set_zlabel("Z")
plt.savefig("Variables_uncorrelated.png",dpi=500)
plt.show()
```





Classes are uncorrelated and their auto-correlation values are different

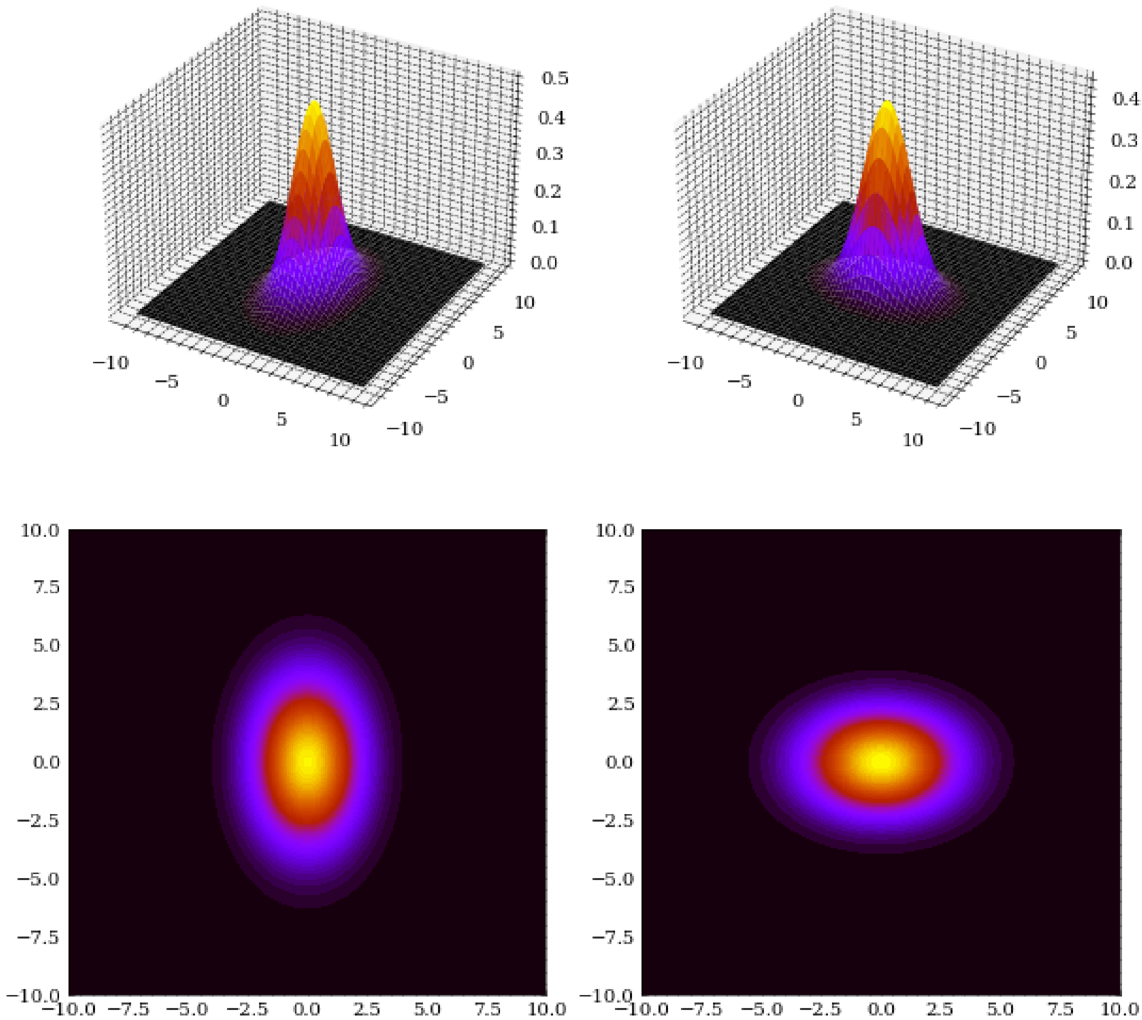


$$\Sigma = \begin{pmatrix} \sigma_x^2 & 0 \\ 0 & \sigma_y^2 \end{pmatrix}$$

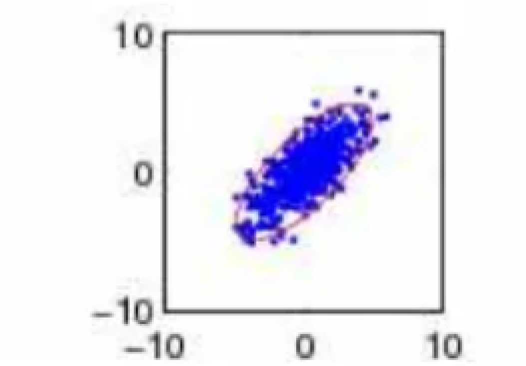
In [39]:

```
covar_matrix = np.identity(number_of_classes)

x1 = np.linspace(-10,10,100)
x2 = np.linspace(-10,10,100)

fig = plt.figure(figsize=(10,10))
# fig , ax = plt.subplots(1,2, figsize=
(16,8),subplot_kw=dict(projection="3d"))

# Editing the auto-correlation values
covar_matrix[0][0] = 2 # x1 autocorrelation value
covar_matrix[1][1] = 5 # x2 autocorrelation value

z,x,y = iter_norm_dis(x1,x2,number_of_classes,covar_matrix,mean)

ax = fig.add_subplot(2,2,1,projection="3d")
ax.plot_surface(x,y,z,cmap="gnuplot")

ax = fig.add_subplot(2,2,3)
ax.contourf(x,y,z,50,cmap="gnuplot")

# Editing the auto-correlation values
covar_matrix[0][0] = 4 # x1 autocorrelation value
covar_matrix[1][1] = 2 # x2 autocorrelation value

ax = fig.add_subplot(2,2,2,projection="3d")
```

```
z,x,y = iter_norm_dis(x1,x2,number_of_classes,covar_matrix,mean)
ax.plot_surface(x,y,z,cmap="gnuplot")

ax = fig.add_subplot(2,2,4)
ax.contourf(x,y,z,50,cmap="gnuplot")

# for i in range(2):
#     ax[i].set_xlabel("X1")
#     ax[i].set_ylabel("X2")
#     ax[i].set_zlabel("Z")

plt.savefig("Variables_uncorrelated_but_nonequal_autocorr.png",dpi=400)
plt.show()
```



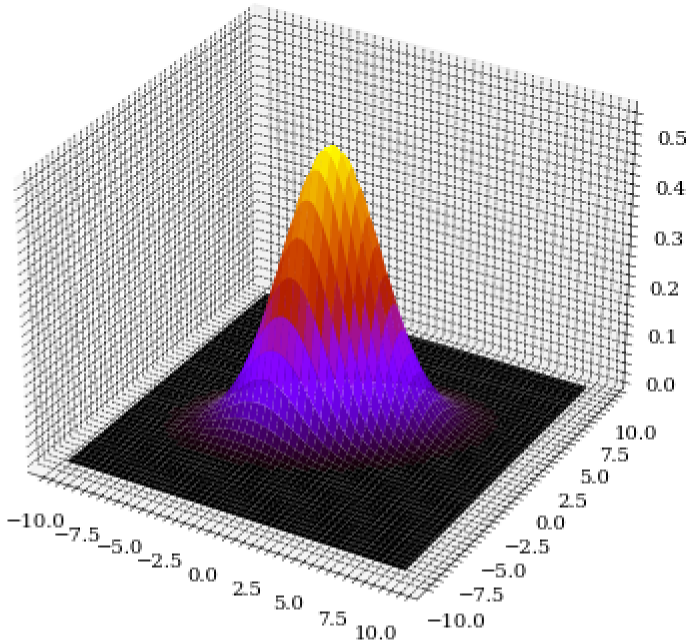
Classes are correlated

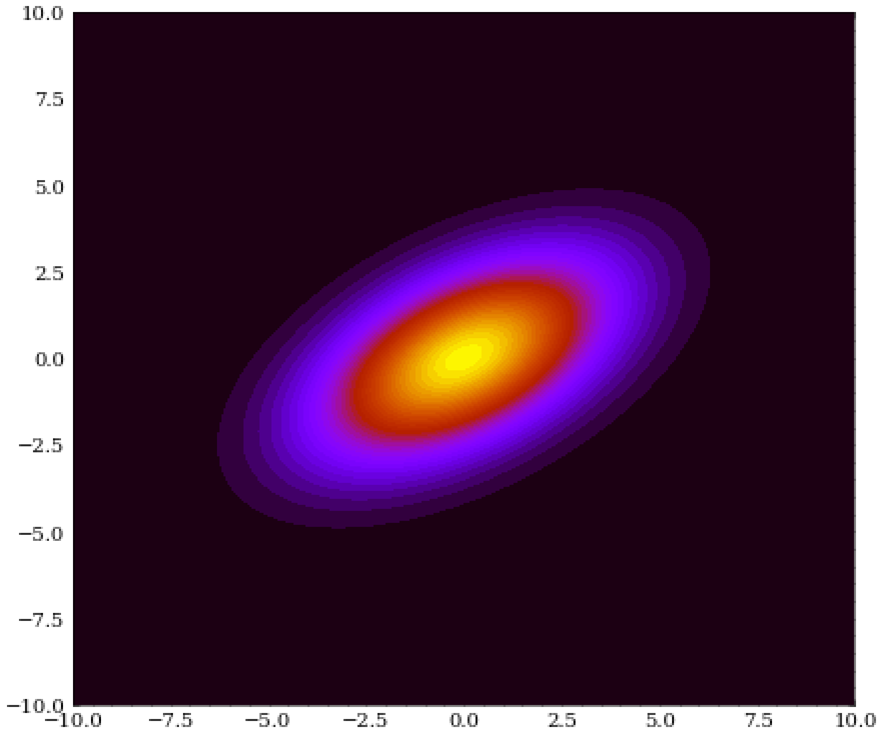


$$\Sigma = \begin{pmatrix} \sigma_x^2 & \rho\sigma_x\sigma_y \\ \rho\sigma_x\sigma_y & \sigma_y^2 \end{pmatrix}$$

In [41]:

```
covar_matrix = np.zeros((number_of_classes,number_of_classes))

# Editing the covariance matrix
covar_matrix[0][0] = 5
covar_matrix[0][1] = 1
covar_matrix[1][0] = 3
covar_matrix[1][1] = 3

x1 = np.linspace(-10,10,100)
x2 = np.linspace(-10,10,100)

z,x,y = iter_norm_dis(x1,x2,number_of_classes,covar_matrix,mean)

fig = plt.figure(figsize=(7,14))
ax = fig.add_subplot(2,1,1,projection='3d')
ax.plot_surface(x,y,z,cmap="gnuplot")

ax = fig.add_subplot(2,1,2)
ax.contourf(x,y,z,50,cmap="gnuplot")

# ax.set_xlabel("X1")
# ax.set_ylabel("X2")
# ax.set_zlabel("Z")
plt.savefig("Variables_correlated.png",dpi=400)
plt.show()
```





Fancy animation stuff

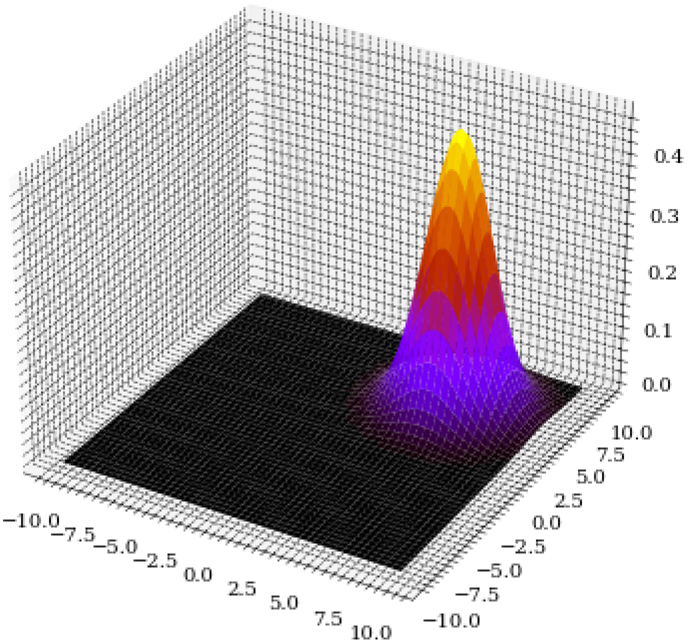
Using matplotlib.animate

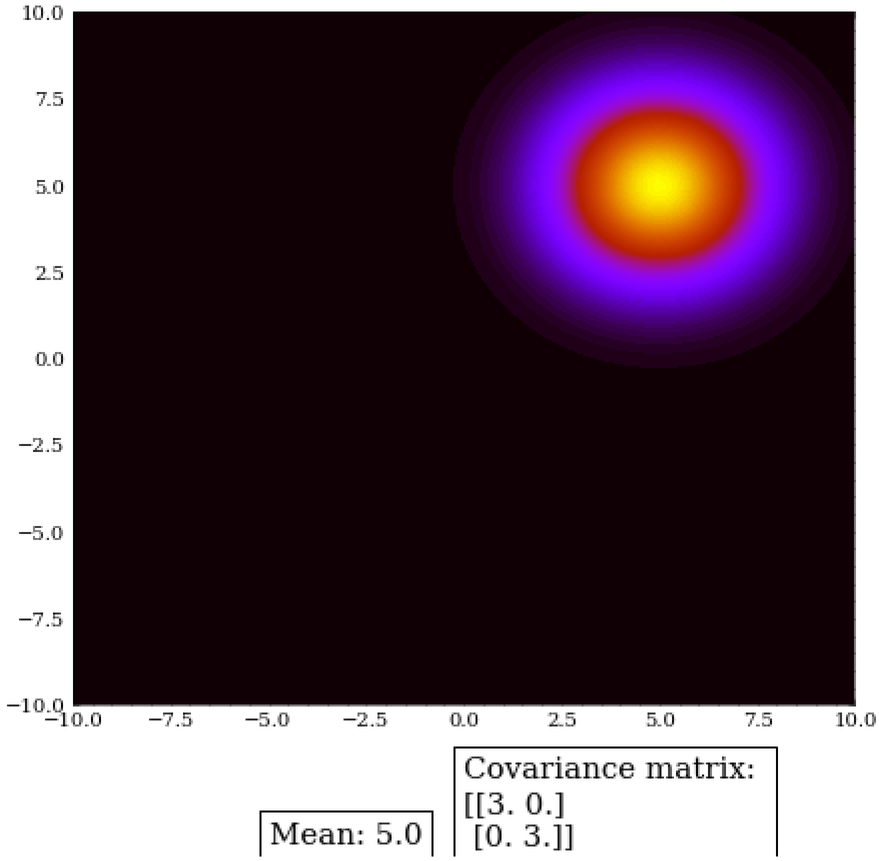
In [77]:
```
from matplotlib.animation import FuncAnimation, PillowWriter
```

Changing the mean value

In [94]:

```
# ranges of input values
x1 = np.linspace(-10,10,100)
x2 = np.linspace(-10,10,100)

# initial values
scaling_factor = 3
covar_matrix = scaling_factor*np.identity(number_of_classes)
mean = 0
# z,x,y = iter_norm_dis(x1,x2,number_of_classes,covar_matrix,mean)

# Start of plotting
fig = plt.figure(figsize=(7,14))

ax3d = fig.add_subplot(2,1,1,projection="3d")
# ax3d.plot_surface(x,y,z,cmap="gnuplot")

ax2d = fig.add_subplot(2,1,2)
ax2d.axis([-15, 15, -15, 15])
# ax2d.contourf(x,y,z,50,cmap="gnuplot")

mean_vals = np.linspace(-5,5,50)
def animate(i):
    global covar_matrix, number_of_classes, mean_vals
    ax2d.clear()
    ax3d.clear()
    mean_i = mean_vals[i]
    z,x,y =
iter_norm_dis(x1,x2,number_of_classes,covar_matrix,mean_i)
    ax2d.contourf(x,y,z,100,cmap="gnuplot")
    ax3d.plot_surface(x,y,z,cmap="gnuplot")
    ax2d.text(-5,-14, f'Mean: {mean_vals[i]}',fontsize=15, bbox=
{'facecolor': 'white','pad': 5})
    ax2d.text(0,-14, f'Covariance matrix:
\n{covar_matrix}',fontsize=15, bbox={'facecolor': 'white','pad': 5})

ani =
FuncAnimation(fig,animate,frames=len(mean_vals),interval=50,repeat=Fals
ani.save("shifting_mean.gif",dpi=300,writer=PillowWriter(fps=24))
```





Changing the Covariance matrix

In [96]:

```
values = [np.array([[1,0],[0,1]]),np.array([[2,0],
[0,4]]),np.array([[4,0],[0,2]]),np.array([[1,0.5],
[0.75,1]]),np.array([[1,0.75],[0.5,1]])]
```

```
mean = 0
def animate(i):
    global covar_matrix, number_of_classes, values, mean
    ax2d.clear()
    ax3d.clear()
    covar_matrix = values[i]
    z,x,y = iter_norm_dis(x1,x2,number_of_classes,covar_matrix,mean)
    ax2d.contourf(x,y,z,100,cmap="gnuplot")
    ax3d.plot_surface(x,y,z,cmap="gnuplot")
    ax2d.text(-5,-14, f'Mean: {mean_vals[i]}',fontsize=15, bbox=
{'facecolor': 'white','pad': 5})
    ax2d.text(0,-14, f'Covariance matrix:
\n{covar_matrix}',fontsize=15, bbox={'facecolor': 'white','pad': 5})

ani =
FuncAnimation(fig,animate,frames=len(values),interval=500,repeat=False)
ani.save("shifting_covariance.gif",dpi=300,writer=PillowWriter(fps=1))
```