In [1]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

In [2]:
```
#function to calculate the loss of a model
def get_loss(x, y, theta):
    """x is input data (m x n)
       y is ground truths (m x 1)
       theta is model params (n x 1)"""
    h = x.dot(theta)
    error = np.subtract(h, y)
    sqError = np.square(error)
    sumSqError = np.sum(sqError)
    avgSqError = sumSqError /(2 * len(y))
    return avgSqError
```

In [3]:
```
#Function to run the gradient descent algorithm
def gradient_descent(x, y, theta, a, iterations):
    """x is input data (m x n)
       y is ground truths (m x 1)
       theta is model params (n x 1)
       a is learn rate (scalar)
       iterations. duh. (scalar)"""
    losses = np.zeros(iterations)
    for i in range(iterations):
        h = x.dot(theta)
        error = np.subtract(h, y)
        delta = x.transpose().dot(error)
        grad = delta / len(y)
        theta = theta - (a * grad)
        losses[i] = get_loss(x, y, theta)
    return theta, losses
```

In [4]:
```
#Read in the CSV into a dataframe
csvData = pd.read_csv("./D3.csv")

csvData.head(5)
```

Out[4]:

	X1	X2	X3	Y
0	0.000000	3.440000	0.440000	4.387545
1	0.040404	0.134949	0.888485	2.679650
2	0.080808	0.829899	1.336970	2.968490
3	0.121212	1.524848	1.785455	3.254065
4	0.161616	2.219798	2.233939	3.536375

In [5]:
```
#Begin Part A Code
```

In [6]:
```
#SETTINGS for Part A
# Learn rate
LEARN_RATE = 0.025
# Gradient descent iterations
ITERATIONS = 1000
```

In [7]:
```
#convert the dataframe into formatted np arrays

csvCols = len(csvData.columns)
csvRows = len(csvData)

y = csvData.values[:,csvCols-1].reshape(csvRows, 1)

y[0:5,:]
```

Out[7]:
```
array([[4.38754501],
       [2.6796499 ],
       [2.96848981],
       [3.25406475],
       [3.53637472]])
```

In [8]:
```
#format x1 values
x1 = np.ones((csvRows, 1))
col1 = csvData.values[:,0].reshape(csvRows, 1)
x1 = np.hstack((x1, col1))

x1[0:5,:]
```

Out[8]:
```
array([[1.        , 0.        ],
       [1.        , 0.04040404],
       [1.        , 0.08080808],
       [1.        , 0.12121212],
       [1.        , 0.16161616]])
```

In [9]:
```
#format x2 values
x2 = np.ones((csvRows, 1))
col2 = csvData.values[:,1].reshape(csvRows, 1)
x2 = np.hstack((x2, col2))

x2[0:5,:]
```

Out[9]:
```
array([[1.        , 3.44      ],
       [1.        , 0.1349495 ],
       [1.        , 0.82989899],
       [1.        , 1.52484848],
       [1.        , 2.21979798]])
```

In [10]:
```
#format x3 values
x3 = np.ones((csvRows, 1))
col3 = csvData.values[:,2].reshape(csvRows, 1)
x3 = np.hstack((x3, col3))

x3[0:5,:]
```

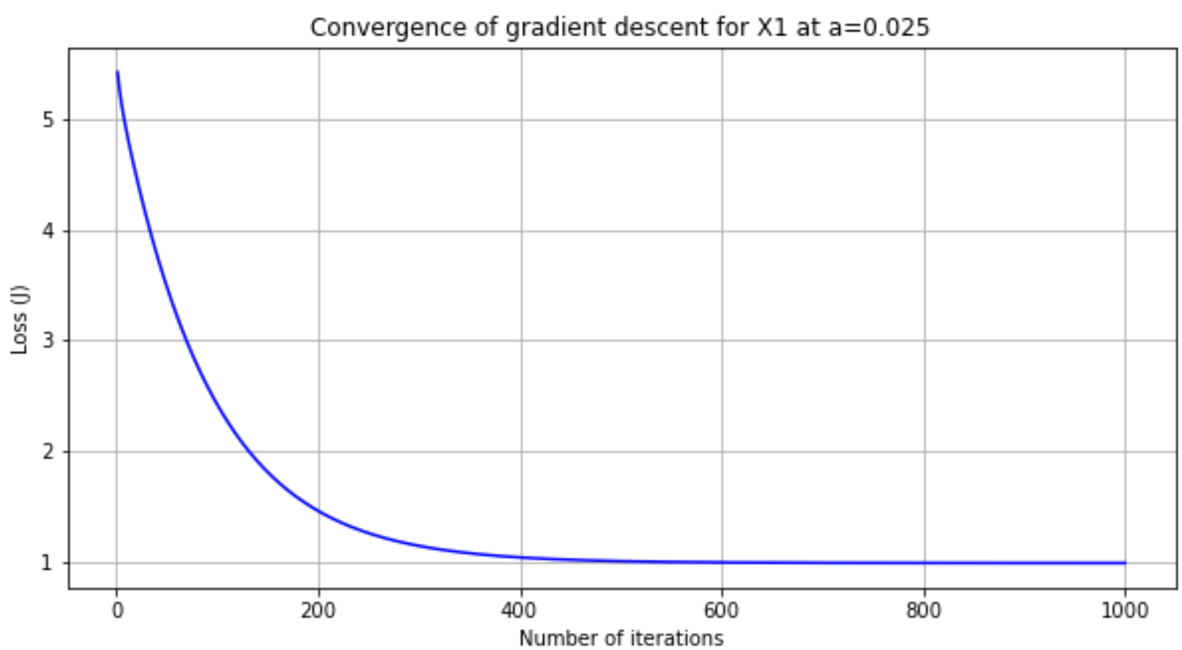
Out[10]:
```
array([[1.        , 0.44      ],
       [1.        , 0.88848485],
       [1.        , 1.3369697 ],
       [1.        , 1.78545454],
       [1.        , 2.23393939]])
```

In [11]:
```
#Run the gradient descent
theta1 = np.zeros((2,1))
theta1, loss1 = gradient_descent(x1,y,theta1,LEARN_RATE,ITERATIONS)

print("Converged Loss for h(X1): {0:.3f}".format(loss1[ITERATIONS-1]))
print("Trained Model for h(X1) = {0:.3f} X1 + {1:.3f}".format(theta1[1,0],thet

plt.rcParams["figure.figsize"] = (10,5)
plt.grid()
plt.xlabel('Number of iterations')
plt.ylabel('Loss (J)')
plt.title('Convergence of gradient descent for X1 at a={}'.format(LEARN_RATE))
plt.plot(range(1, ITERATIONS + 1),loss1, color='blue');
```

```
Converged Loss for h(X1): 0.985
Trained Model for h(X1) = -2.030 X1 + 5.905
```

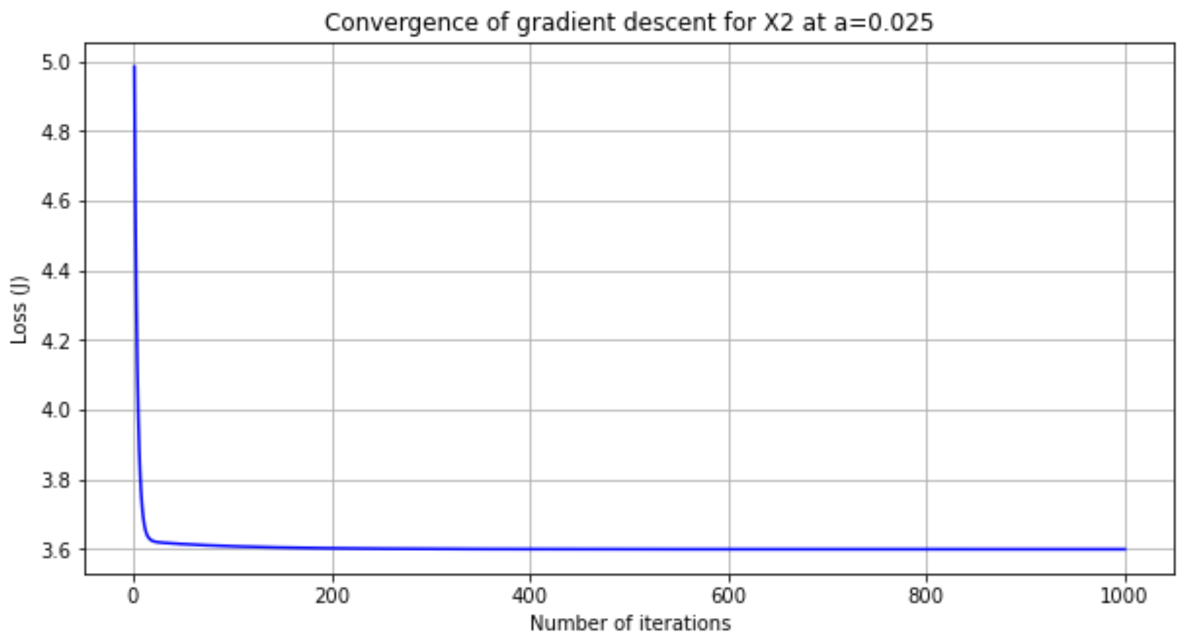


In [12]:
```
#Run the gradient descent
theta2 = np.zeros((2,1))
theta2, loss2 = gradient_descent(x2,y,theta2,LEARN_RATE,ITERATIONS)

print("Converged Loss for h(X2): {0:.3f}".format(loss2[ITERATIONS-1]))
print("Trained Model for h(X2) = {0:.3f} X2 + {1:.3f}".format(theta2[1,0],thet

plt.rcParams["figure.figsize"] = (10,5)
plt.grid()
plt.xlabel('Number of iterations')
plt.ylabel('Loss (J)')
plt.title('Convergence of gradient descent for X2 at a={}'.format(LEARN_RATE))
plt.plot(range(1, ITERATIONS + 1),loss2, color='blue');
```

```
Converged Loss for h(X2): 3.599
Trained Model for h(X2) = 0.558 X2 + 0.734
```

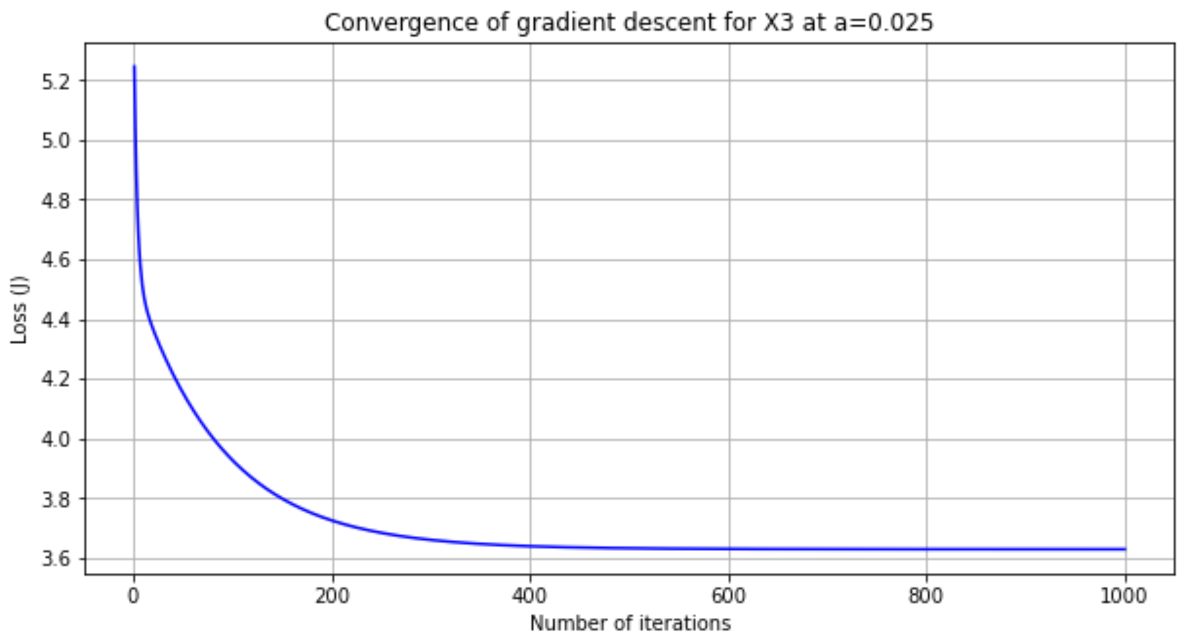


In [13]:
```
#Run the gradient descent
theta3 = np.zeros((2,1))
theta3, loss3 = gradient_descent(x3,y,theta3,LEARN_RATE,ITERATIONS)

print("Converged Loss for X3: {0:.3f}".format(loss3[ITERATIONS-1]))
print("Trained Model for h(X3) = {0:.3f} X3 + {1:.3f}".format(theta3[1,0],thet

plt.rcParams["figure.figsize"] = (10,5)
plt.grid()
plt.xlabel('Number of iterations')
plt.ylabel('Loss (J)')
plt.title('Convergence of gradient descent for X3 at a={}'.format(LEARN_RATE))
plt.plot(range(1, ITERATIONS + 1),loss3, color='blue');
```

```
Converged Loss for X3: 3.629
Trained Model for h(X3) = -0.517 X3 + 2.862
```



In [14]:
```
#End Part A Code,
#Begin Part B code
```

In [15]:
```
#SETTINGS for Part B
# Learn rate
LEARN_RATE = 0.055
# Gradient descent iterations
ITERATIONS = 1000
```

In [16]:
```
#convert the dataframe into formatted np arrays

#initialize some variables
csvCols = len(csvData.columns)
csvRows = len(csvData)

x = np.ones((csvRows, 1))
y = csvData.values[:,csvCols-1].reshape(csvRows, 1)
for i in range(0,csvCols-1): #populate x
    col = csvData.values[:,i].reshape(csvRows, 1)
    x = np.hstack((x, col))

print("first two X")
print(x[0:2,:])
print("first two Y")
print(y[0:2,:])
```

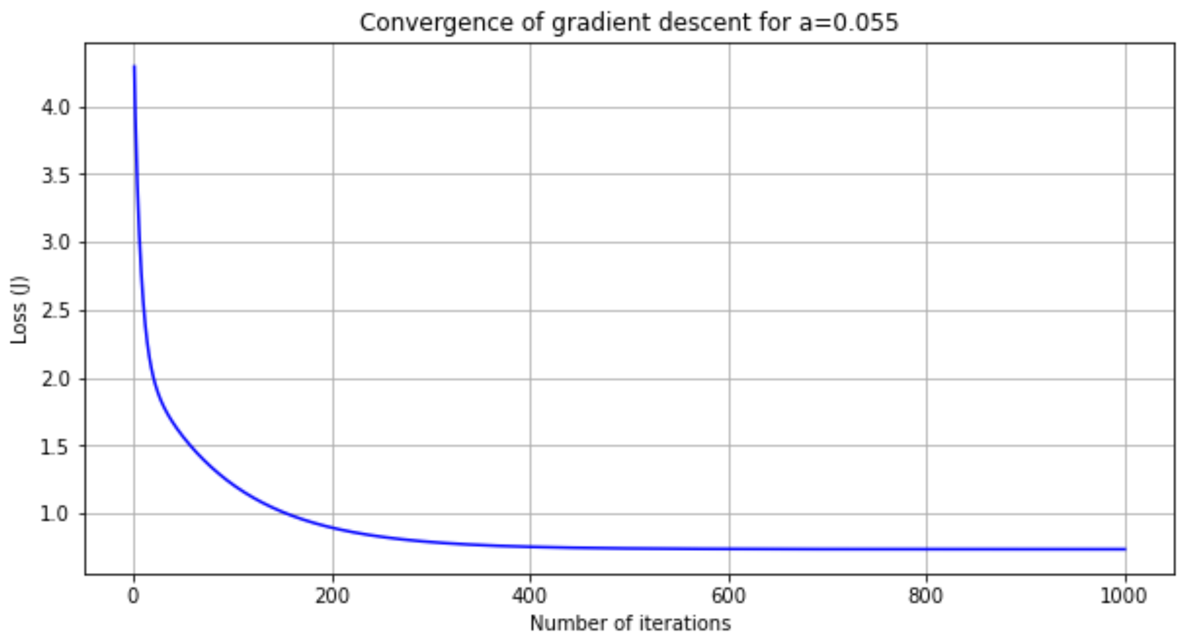
```
first two X
[[1.         0.         3.44       0.44      ]
 [1.         0.04040404 0.1349495  0.88848485]]
first two Y
[[4.38754501]
 [2.6796499 ]]
```

In [17]:
```
#Run the gradient descent
theta = np.zeros((csvCols,1))
theta, loss = gradient_descent(x,y,theta,LEARN_RATE,ITERATIONS)
print("Converged Loss J = {:.3f}".format(loss[ITERATIONS-1]))
print("Trained Model h(X1,X2,X3) = {0:.3f} X1 + {1:.3f} X2 + {2:.3f} X3 + {3:.
      .format(float(theta[1]),float(theta[2]),float(theta[3]),float(theta[0]))

plt.rcParams["figure.figsize"] = (10,5)
plt.grid()
plt.xlabel('Number of iterations')
plt.ylabel('Loss (J)')
plt.title('Convergence of gradient descent for a={}'.format(LEARN_RATE))
plt.plot(range(1, ITERATIONS + 1),loss, color='blue')
```

```
Converged Loss J = 0.738
Trained Model h(X1,X2,X3) = -2.001 X1 + 0.536 X2 + -0.262 X3 + 5.293
```

Out[17]:
```
[<matplotlib.lines.Line2D at 0x1ec395bd1f0>]
```



In [18]:
```
XV = np.array([[1, 1, 1],[2, 0, 4],[3, 2, 1]])
XV = np.hstack((np.ones((3, 1)), XV))
print("XV")
print(XV)
H = XV.dot(theta)
print("h(XV)")
print(H)
```

```
XV
[[1. 1. 1. 1.]
 [1. 2. 0. 4.]
 [1. 3. 2. 1.]]
h(XV)
[[3.56577916]
 [0.24153226]
 [0.10042608]]
```