# Homework #7

**20171621 민대인**

## 1. 목차

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In [76]:
```
#-- 리스트 7-1-(1)
import numpy as np
# 데이터 생성 ------------------
np.random.seed(seed=1)
N =200
K = 3
T = np.zeros((N, 3), dtype=np.uint8)
X = np.zeros((N, 2))
X_range0 = [-3, 3]
X_range1 = [-3, 3]
Mu = np.array([[-.5, -.5], [.5, 1.0], [1, -.5]])
Sig = np.array([[.7, .7], [.8, .3], [.3, .8]])
Pi = np.array([0.4, 0.8, 1])
for n in range(N):
    wk = np.random.rand()
    for k in range(K):
        if wk < Pi[k]:
            T[n, k] = 1
            break
    for k in range(2):
        X[n, k] = np.random.randn() * Sig[T[n, :] == 1, k] + \
        Mu[T[n, :] == 1, k]
```

In [77]:
```
#-- 리스트 7-1-(2)
# ------------ 2 분류 데이터를 테스트 훈련 데이터로 분할
TestRatio = 0.5
X_n_training = int(N * TestRatio)
X_train = X[:X_n_training, :]
X_test = X[X_n_training:, :]
T_train = T[:X_n_training, :]
T_test = T[X_n_training:, :]


# -------------- 데이터를 'class_data.npz'에 저장
np.savez('class_data.npz', X_train=X_train, T_train=T_train, X_test=X_test, T_test=T_tes
```

In [78]:
```
# -- 리스트 7-1-(3)
import matplotlib.pyplot as plt
%matplotlib inline


# 데이터를 그리기 ------------------
def Show_data(x, t):
```

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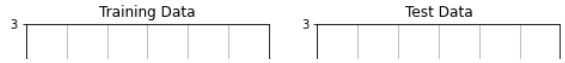
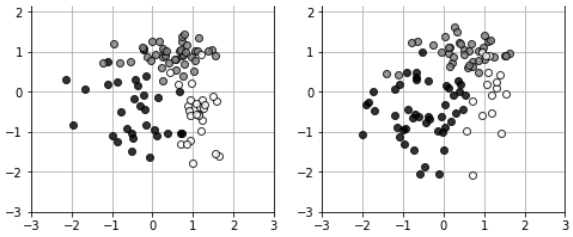
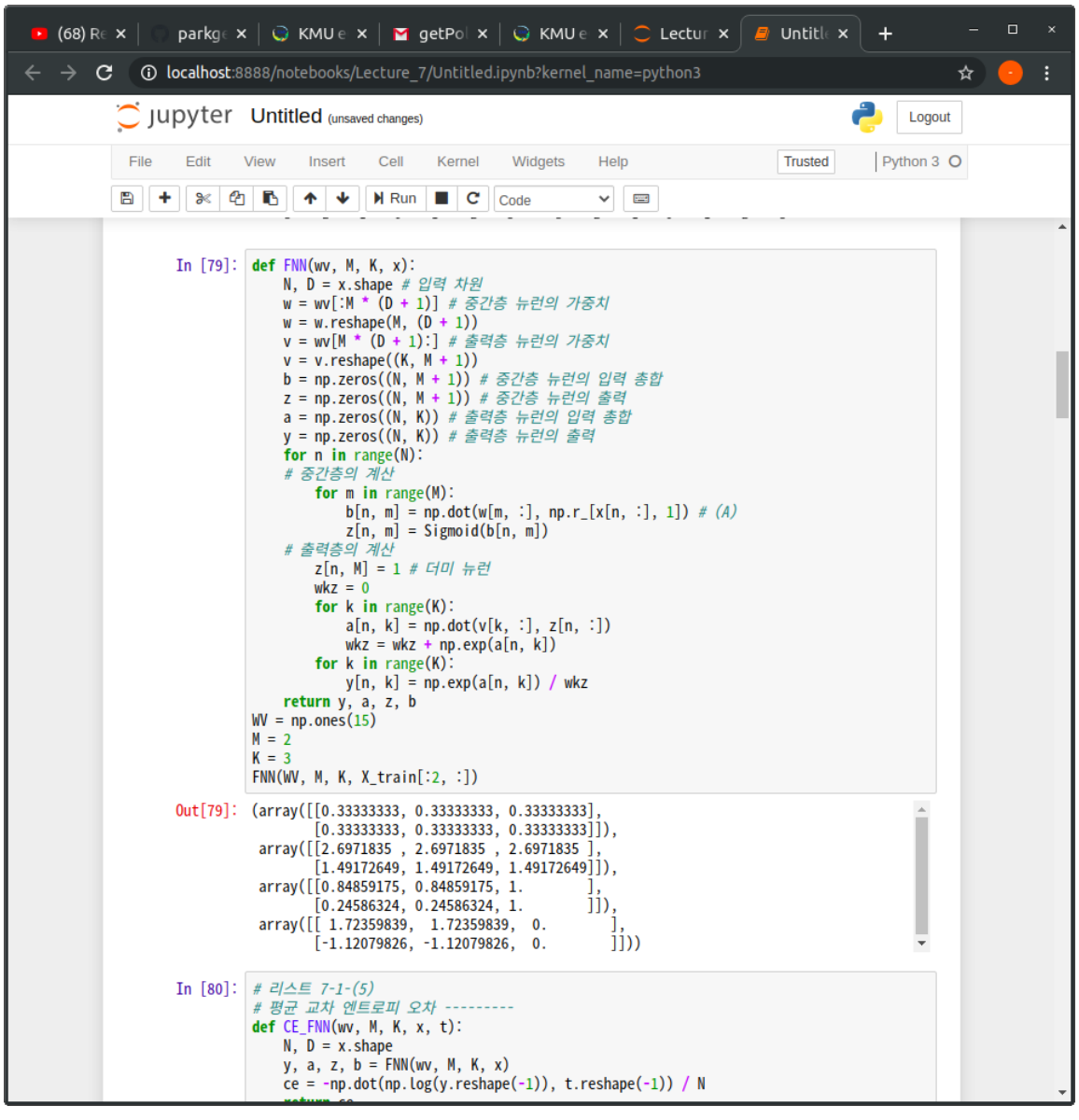
Run Code

```
import matplotlib.pyplot as plt
%matplotlib inline


# 데이터를 그리기 ------------------
def Show_data(x, t):
    wk, n = t.shape
    c = [[0, 0, 0], [.5, .5, .5], [1, 1, 1]]
    for i in range(n):
        plt.plot(x[t[:, i] == 1, 0], x[t[:, i] == 1, 1], linestyle='none', marker='o', m
    plt.grid(True)

# 메인 ----------------------------
plt.figure(1, figsize=(8, 3.7))
plt.subplot(1, 2, 1)
Show_data(X_train, T_train)
plt.xlim(X_range0)
plt.ylim(X_range1)
plt.title('Training Data')
plt.subplot(1, 2, 2)
Show_data(X_test, T_test)
plt.xlim(X_range0)
plt.ylim(X_range1)
plt.title('Test Data')
plt.show()
```





```
In [79]: def FNN(wv, M, K, x):
             N, D = x.shape # 입력 차원
             w = wv[:M * (D + 1)] # 중간층 뉴런의 가중치
             w = w.reshape(M, (D + 1))
```



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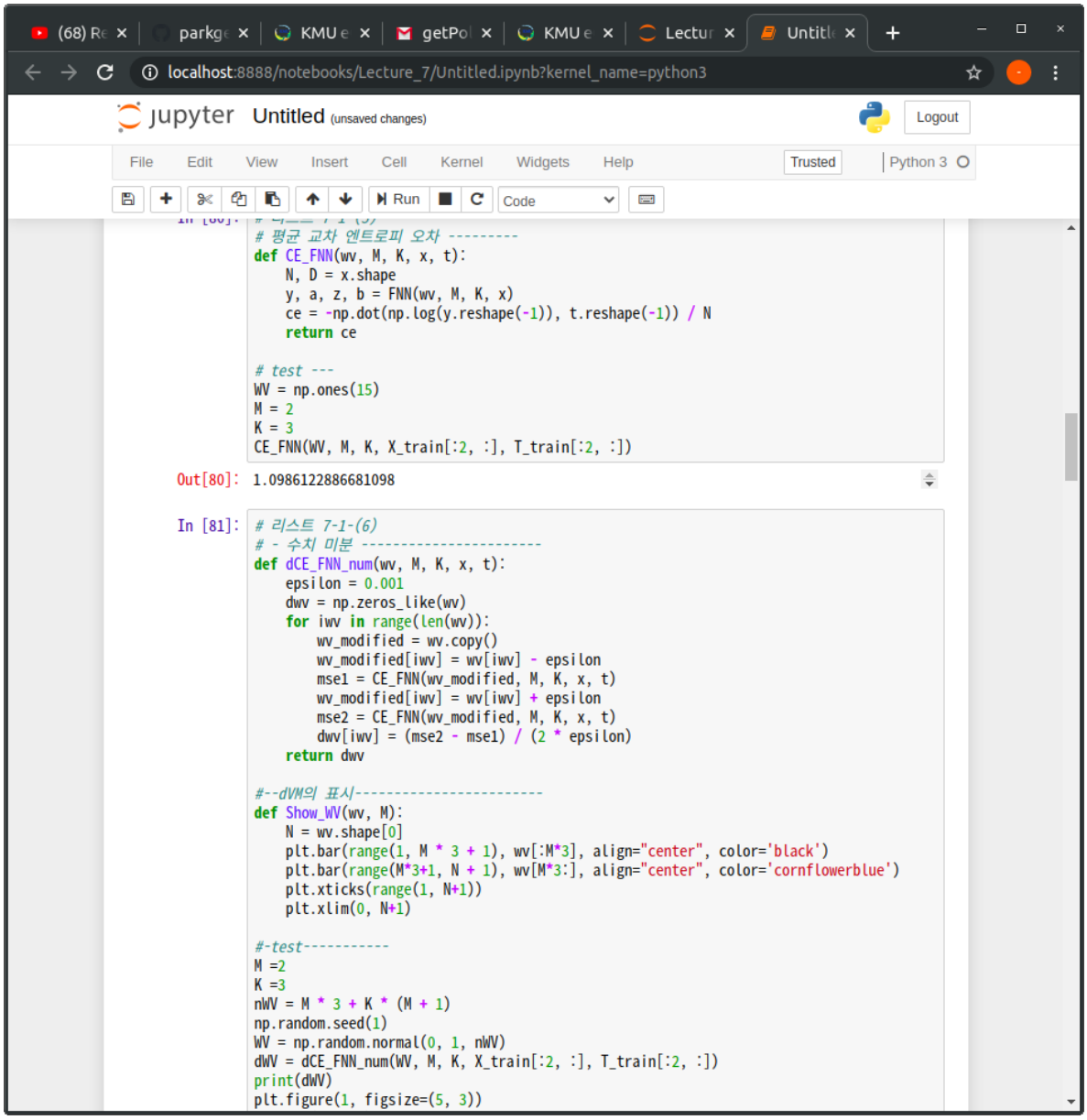
Run Code

```
In [79]: def FNN(wv, M, K, x):
             N, D = x.shape # 입력 차원
             w = wv[:M * (D + 1)] # 중간층 뉴런의 가중치
             w = w.reshape(M, (D + 1))
             v = wv[M * (D + 1):] # 출력층 뉴런의 가중치
             v = v.reshape((K, M + 1))
             b = np.zeros((N, M + 1)) # 중간층 뉴런의 입력 총합
             z = np.zeros((N, M + 1)) # 중간층 뉴런의 출력
             a = np.zeros((N, K)) # 출력층 뉴런의 입력 총합
             y = np.zeros((N, K)) # 출력층 뉴런의 출력
             for n in range(N):
             # 중간층의 계산
                 for m in range(M):
                     b[n, m] = np.dot(w[m, :], np.r_[x[n, :], 1]) # (A)
                     z[n, m] = Sigmoid(b[n, m])
             # 출력층의 계산
                 z[n, M] = 1 # 더미 뉴런
                 wkz = 0
                 for k in range(K):
                     a[n, k] = np.dot(v[k, :], z[n, :])
                     wkz = wkz + np.exp(a[n, k])
                 for k in range(K):
                     y[n, k] = np.exp(a[n, k]) / wkz
             return y, a, z, b
         WV = np.ones(15)
         M = 2
         K = 3
         FNN(WV, M, K, X_train[:2, :])
```

```
Out[79]: (array([[0.33333333, 0.33333333, 0.33333333],
                 [0.33333333, 0.33333333, 0.33333333]]),
          array([[2.6971835 , 2.6971835 , 2.6971835 ],
                 [1.49172649, 1.49172649, 1.49172649]]),
          array([[0.84859175, 0.84859175, 1.        ],
                 [0.24586324, 0.24586324, 1.        ]]),
          array([[ 1.72359839,  1.72359839,  0.        ],
                 [-1.12079826, -1.12079826,  0.        ]]))
```

```
In [80]: # 리스트 7-1-(5)
         # 평균 교차 엔트로피 오차 ---------
         def CE_FNN(wv, M, K, x, t):
             N, D = x.shape
             y, a, z, b = FNN(wv, M, K, x)
             ce = -np.dot(np.log(y.reshape(-1)), t.reshape(-1)) / N
```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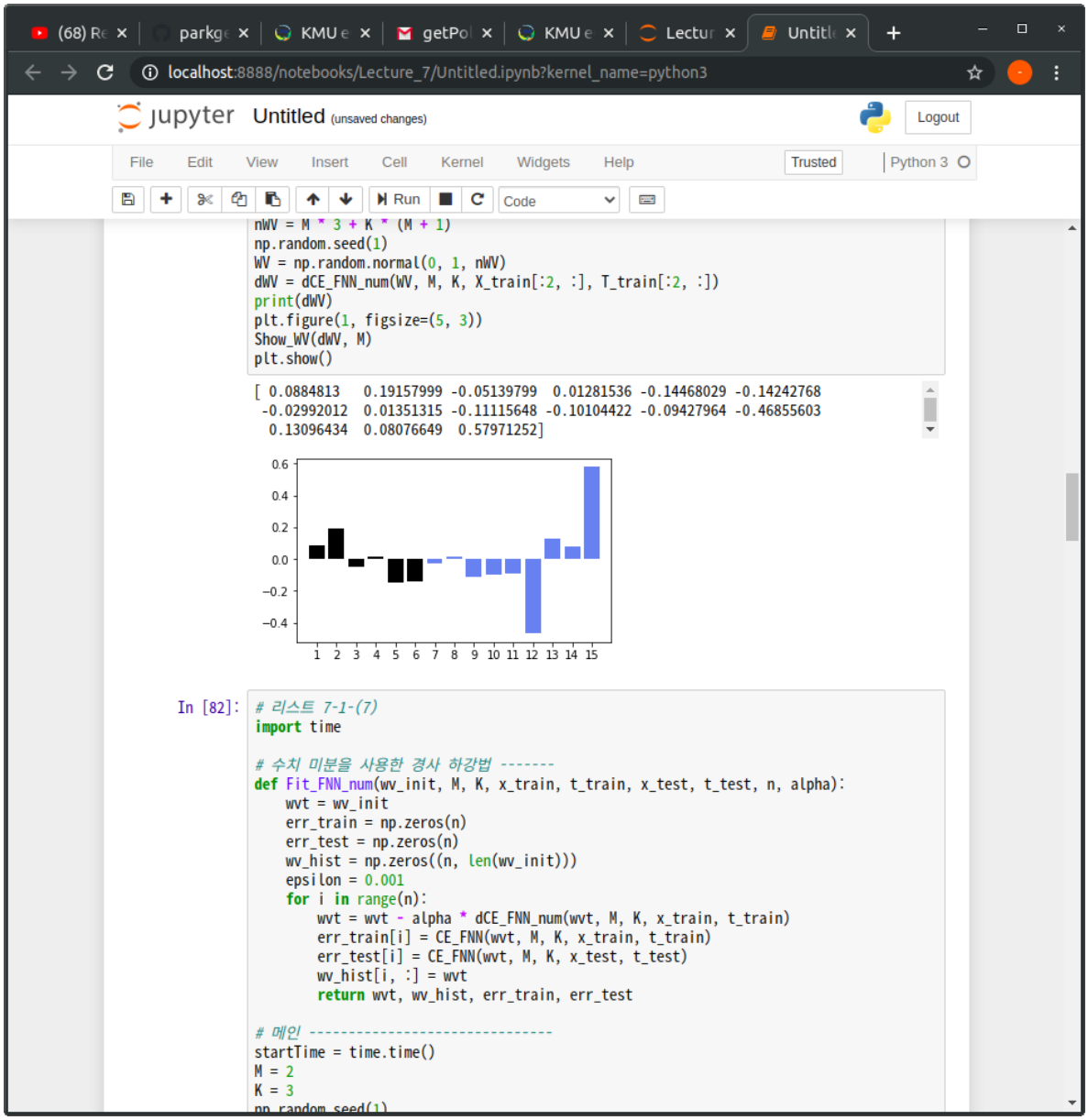
Code
# 평균 교차 엔트로피 오차 ---------
def CE_FNN(wv, M, K, x, t):
N, D = x.shape
y, a, z, b = FNN(wv, M, K, x)
ce = -np.dot(np.log(y.reshape(-1)), t.reshape(-1)) / N
return ce
# test ---
WV = np.ones(15)
M = 2
K = 3
CE_FNN(WV, M, K, X_train[:2, :], T_train[:2, :])
Out[80]: 1.0986122886681098
In [81]:
# 리스트 7-1-(6)
# - 수치 미분 ----------
def dCE_FNN_num(wv, M, K, x, t):
epsilon = 0.001
dwv = np.zeros_like(wv)
for iwv in range(len(wv)):
wv_modified = wv.copy()
wv_modified[iwv] = wv[iwv] - epsilon
mse1 = CE_FNN(wv_modified, M, K, x, t)
wv_modified[iwv] = wv[iwv] + epsilon
mse2 = CE_FNN(wv_modified, M, K, x, t)
dwv[iwv] = (mse2 - mse1) / (2 * epsilon)
return dwv
#--dWM의 표시----------
def Show_WV(wv, M):
N = wv.shape[0]
plt.bar(range(1, M * 3 + 1), wv[:M*3], align="center", color='black')
plt.bar(range(M*3+1, N + 1), wv[M*3:], align="center", color='cornflowerblue')
plt.xticks(range(1, N+1))
plt.xlim(0, N+1)
#-test----------
M =2
K =3
nWV = M * 3 + K * (M + 1)
np.random.seed(1)
WV = np.random.normal(0, 1, nWV)
dWV = dCE_FNN_num(WV, M, K, X_train[:2, :], T_train[:2, :])
print(dWV)
plt.figure(1, figsize=(5, 3))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nWV = M * 3 + K * (M + 1)
np.random.seed(1)
WV = np.random.normal(0, 1, nWV)
dWV = dCE_FNN_num(WV, M, K, X_train[:2, :], T_train[:2, :])
print(dWV)
plt.figure(1, figsize=(5, 3))
Show_WV(dWV, M)
plt.show()
[ 0.0884813  0.19157999 -0.05139799  0.01281536 -0.14468029 -0.14242768
 -0.02992012  0.01351315 -0.11115648 -0.10104422 -0.09427964 -0.46855603
  0.13096434  0.08076649  0.57971252]
0.6
0.4
0.2
0.0
−0.2
−0.4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
In [82]:
# 리스트 7-1-(7)
import time
# 수치 미분을 사용한 경사 하강법 -------
def Fit_FNN_num(wv_init, M, K, x_train, t_train, x_test, t_test, n, alpha):
wvt = wv_init
err_train = np.zeros(n)
err_test = np.zeros(n)
wv_hist = np.zeros((n, len(wv_init)))
epsilon = 0.001
for i in range(n):
wvt = wvt - alpha * dCE_FNN_num(wvt, M, K, x_train, t_train)
err_train[i] = CE_FNN(wvt, M, K, x_train, t_train)
err_test[i] = CE_FNN(wvt, M, K, x_test, t_test)
wv_hist[i, :] = wvt
return wvt, wv_hist, err_train, err_test
# 메인 ------------------------------
startTime = time.time()
M = 2
K = 3
np.random.seed(1)

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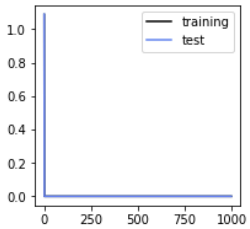
Run Code

```
# 메인 ------------------------------
startTime = time.time()
M = 2
K = 3
np.random.seed(1)
WV_init = np.random.normal(0,0.01, M*3+K *(M+1))
N_step = 1000 # (B) 학습 단계
alpha = 0.5
WV, WV_hist, Err_train, Err_test = Fit_FNN_num(WV_init, M ,K, X_train, T_train, X_test,
calculation_time = time.time() - startTime
print("Calculation time : {0:.3f} sec".format(calculation_time))
```

```
Calculation time : 0.248 sec
```

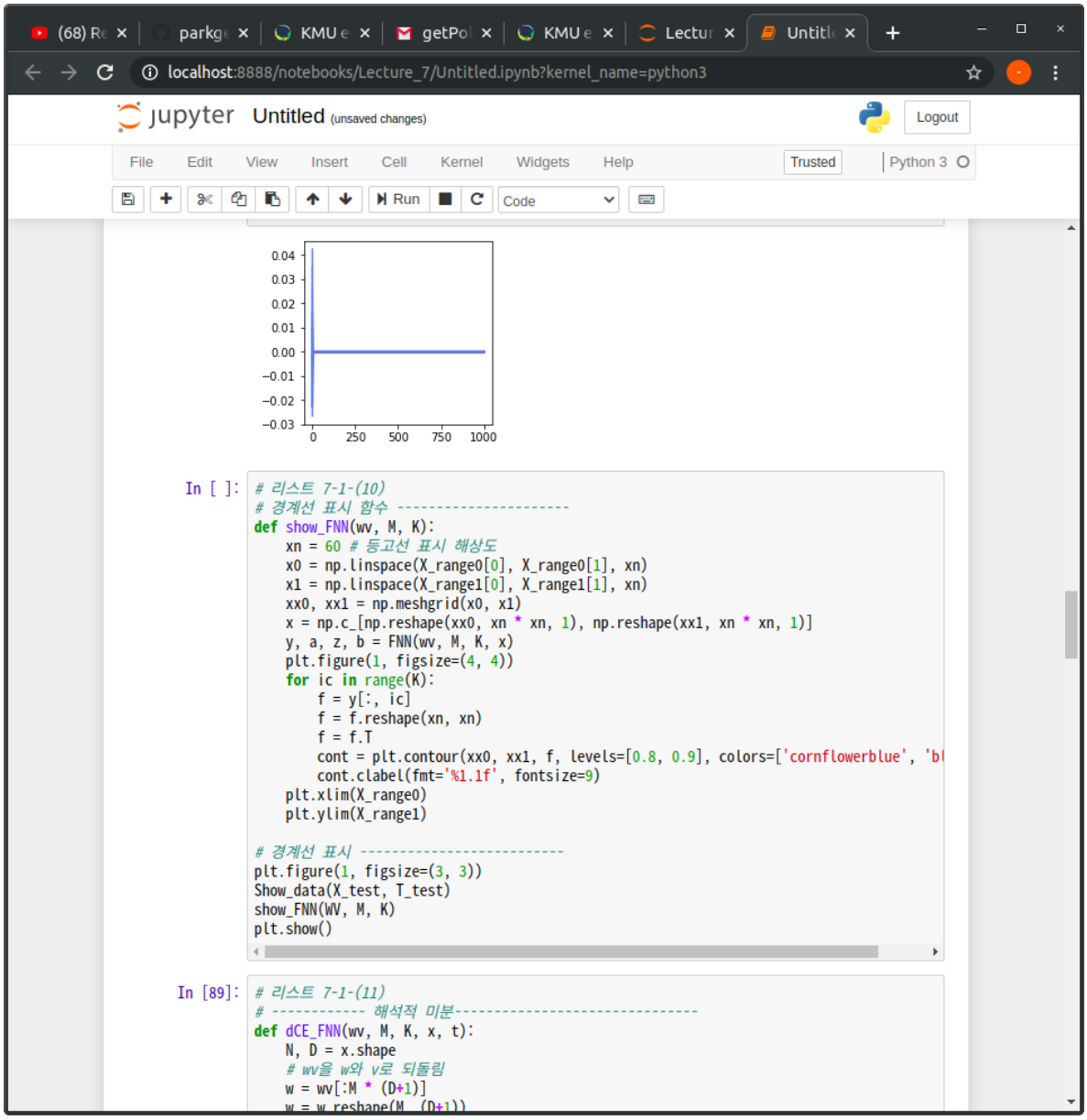
In [83]:

```
# 리스트 7-1-(8)
# 학습 오차의 표시 ------------------------------
plt.figure(1, figsize=(3,3))
plt.plot(Err_train, 'black', label='training')
plt.plot(Err_test, 'cornflowerblue', label='test')
plt.legend()
plt.show()
```




In [84]:

```
plt.figure(1, figsize=(3, 3))
plt.plot(WV_hist[:, :M*3], 'black')
plt.plot(WV_hist[:, M*3:], 'cornflowerblue')
plt.show()
```



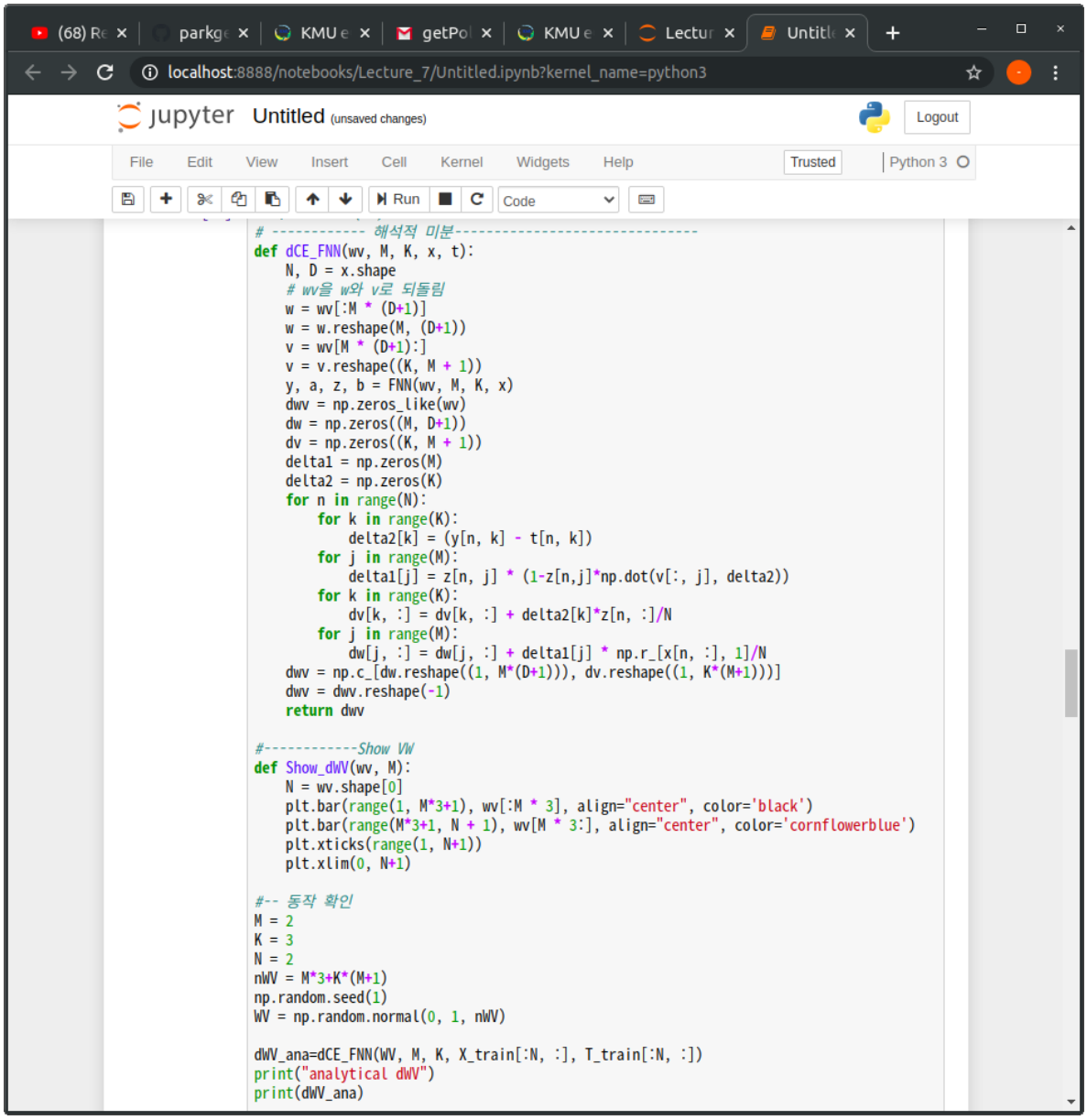

In [ ]:

```
# 리스트 7-1-(10)
# 경계선 표시 함수 ----------------------
def show_FNN(wv, M, K):
    xn = 60 # 등고선 표시 해상도
    x0 = np.linspace(X_range0[0], X_range0[1], xn)
    x1 = np.linspace(X_range1[0], X_range1[1], xn)
    xx0, xx1 = np.meshgrid(x0, x1)
    x = np.c_[np.reshape(xx0, xn * xn, 1), np.reshape(xx1, xn * xn, 1)]
    y, a, z, b = FNN(wv, M, K, x)
    plt.figure(1, figsize=(4, 4))
    for ic in range(K):
        f = y[:, ic]
        f = f.reshape(xn, xn)
        f = f.T
        cont = plt.contour(xx0, xx1, f, levels=[0.8, 0.9], colors=['cornflowerblue', 'bl
        cont.clabel(fmt='%1.1f', fontsize=9)
    plt.xlim(X_range0)
    plt.ylim(X_range1)

# 경계선 표시 -------------------------
plt.figure(1, figsize=(3, 3))
Show_data(X_test, T_test)
show_FNN(WV, M, K)
plt.show()
```

In [89]:

```
# 리스트 7-1-(11)
# ----------- 해석적 미분------------------------------
def dCE_FNN(wv, M, K, x, t):
    N, D = x.shape
    # wv을 w와 v로 되돌림
    w = wv[:M * (D+1)]
    w = w.reshape(M, (D+1))
```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Code
# ------------ 해석적 미분------------------------------
def dCE_FNN(wv, M, K, x, t):
N, D = x.shape
# wv을 w와 v로 되돌림
w = wv[:M * (D+1)]
w = w.reshape(M, (D+1))
v = wv[M * (D+1):]
v = v.reshape((K, M + 1))
y, a, z, b = FNN(wv, M, K, x)
dwv = np.zeros_like(wv)
dw = np.zeros((M, D+1))
dv = np.zeros((K, M + 1))
delta1 = np.zeros(M)
delta2 = np.zeros(K)
for n in range(N):
for k in range(K):
delta2[k] = (y[n, k] - t[n, k])
for j in range(M):
delta1[j] = z[n, j] * (1-z[n,j]*np.dot(v[:, j], delta2))
for k in range(K):
dv[k, :] = dv[k, :] + delta2[k]*z[n, :]/N
for j in range(M):
dw[j, :] = dw[j, :] + delta1[j] * np.r_[x[n, :], 1]/N
dwv = np.c_[dw.reshape((1, M*(D+1))), dv.reshape((1, K*(M+1)))]
dwv = dwv.reshape(-1)
return dwv
#------------Show VW
def Show_dWV(wv, M):
N = wv.shape[0]
plt.bar(range(1, M*3+1), wv[:M * 3], align="center", color='black')
plt.bar(range(M*3+1, N + 1), wv[M * 3:], align="center", color='cornflowerblue')
plt.xticks(range(1, N+1))
plt.xlim(0, N+1)
#-- 동작 확인
M = 2
K = 3
N = 2
nWV = M*3+K*(M+1)
np.random.seed(1)
WV = np.random.normal(0, 1, nWV)
dWV_ana=dCE_FNN(WV, M, K, X_train[:N, :], T_train[:N, :])
print("analytical dWV")
print(dWV_ana)

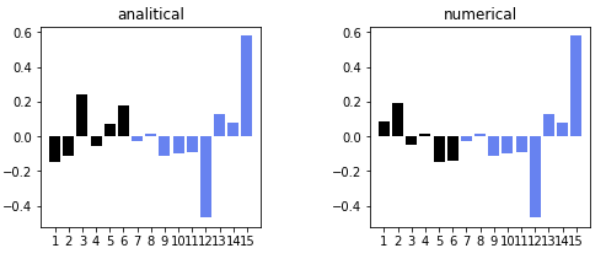
```
WV = np.random.normal(0, 1, nWV)

dWV_ana=dCE_FNN(WV, M, K, X_train[:N, :], T_train[:N, :])
print("analytical dWV")
print(dWV_ana)

dWV_num = dCE_FNN_num(WV, M, K, X_train[:N, :], T_train[:N, :])
print("numerical dWV")
print(dWV_num)

plt.figure(1, figsize=(8, 3))
plt.subplots_adjust(wspace=0.5)
plt.subplot(1, 2, 1)
Show_dWV(dWV_ana, M)
plt.title('analitical')
plt.subplot(1, 2, 2)
Show_dWV(dWV_num, M)
plt.title('numerical')
plt.show()
```

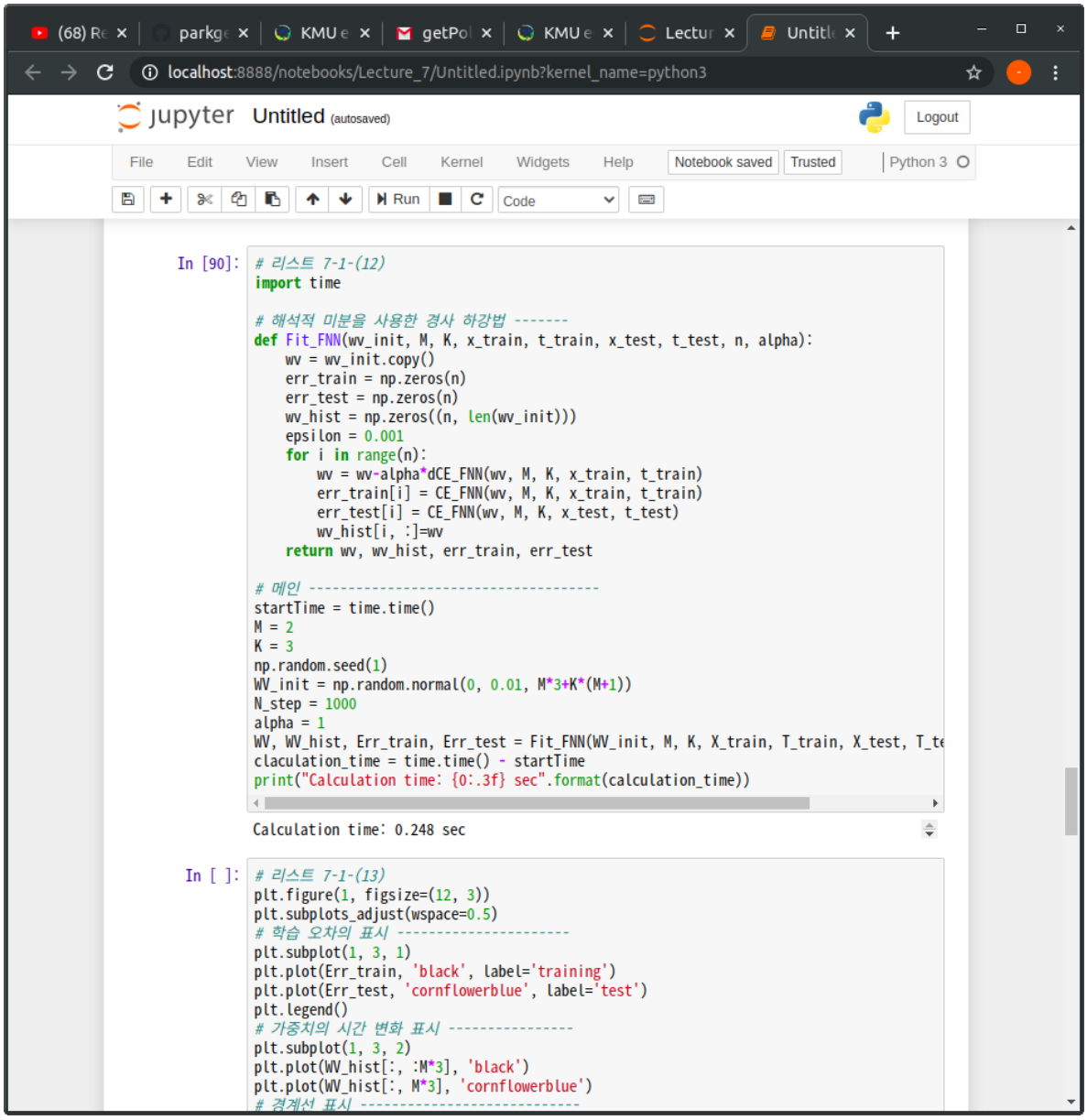
```
analytical dWV
[-0.1454769  -0.11140697  0.24387648 -0.05309351  0.06953083  0.17526663
 -0.02992012  0.01351315 -0.11115649 -0.10104422 -0.09427964 -0.46855604
  0.13096434  0.08076649  0.57971253]
numerical dWV
[ 0.0884813   0.19157999 -0.05139799  0.01281536 -0.14468029 -0.14242768
 -0.02992012  0.01351315 -0.11115648 -0.10104422 -0.09427964 -0.46855603
  0.13096434  0.08076649  0.57971252]
```




In [90]:

```
# 리스트 7-1-(12)
import time

# 해석적 미분을 사용한 경사 하강법 -------
```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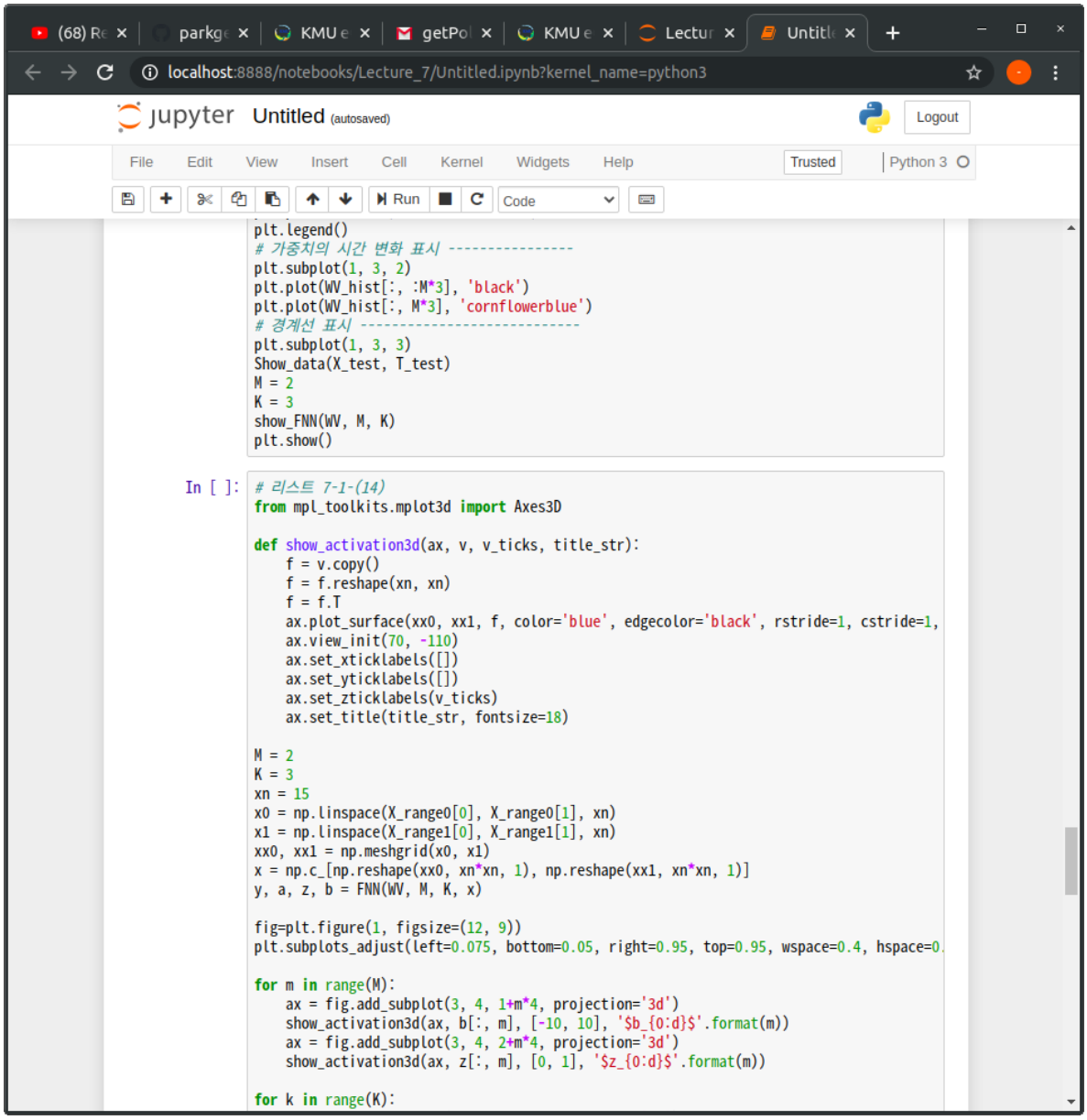
In [90]:
# 리스트 7-1-(12)
import time
# 해석적 미분을 사용한 경사 하강법 -------
def Fit_FNN(wv_init, M, K, x_train, t_train, x_test, t_test, n, alpha):
wv = wv_init.copy()
err_train = np.zeros(n)
err_test = np.zeros(n)
wv_hist = np.zeros((n, len(wv_init)))
epsilon = 0.001
for i in range(n):
wv = wv-alpha*dCE_FNN(wv, M, K, x_train, t_train)
err_train[i] = CE_FNN(wv, M, K, x_train, t_train)
err_test[i] = CE_FNN(wv, M, K, x_test, t_test)
wv_hist[i, :]=wv
return wv, wv_hist, err_train, err_test
# 메인 ------------------------------------
startTime = time.time()
M = 2
K = 3
np.random.seed(1)
WV_init = np.random.normal(0, 0.01, M*3+K*(M+1))
N_step = 1000
alpha = 1
WV, WV_hist, Err_train, Err_test = Fit_FNN(WV_init, M, K, X_train, T_train, X_test, T_te
claculation_time = time.time() - startTime
print("Calculation time: {0:.3f} sec".format(calculation_time))
Calculation time: 0.248 sec
In [ ]:
# 리스트 7-1-(13)
plt.figure(1, figsize=(12, 3))
plt.subplots_adjust(wspace=0.5)
# 학습 오차의 표시 ----------------------
plt.subplot(1, 3, 1)
plt.plot(Err_train, 'black', label='training')
plt.plot(Err_test, 'cornflowerblue', label='test')
plt.legend()
# 가중치의 시간 변화 표시 ----------------
plt.subplot(1, 3, 2)
plt.plot(WV_hist[:, :M*3], 'black')
plt.plot(WV_hist[:, M*3], 'cornflowerblue')
# 경계선 표시 ---------------------------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Python 3
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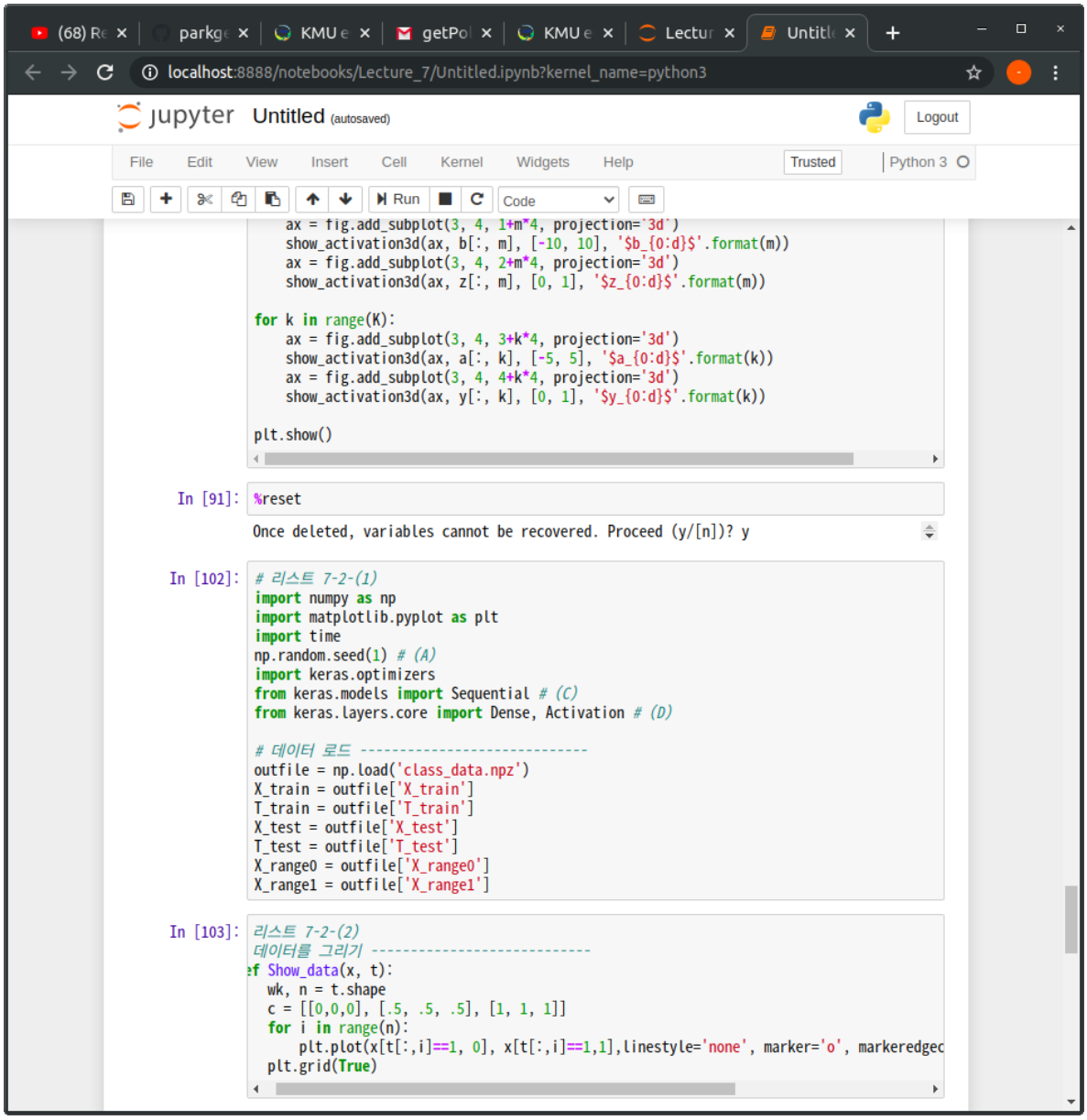
Code
plt.legend()
# 가중치의 시간 변화 표시 ----------
plt.subplot(1, 3, 2)
plt.plot(WV_hist[:, :M*3], 'black')
plt.plot(WV_hist[:, M*3], 'cornflowerblue')
# 경계선 표시 ----------
plt.subplot(1, 3, 3)
Show_data(X_test, T_test)
M = 2
K = 3
show_FNN(WV, M, K)
plt.show()
In [ ]:
# 리스트 7-1-(14)
from mpl_toolkits.mplot3d import Axes3D
def show_activation3d(ax, v, v_ticks, title_str):
f = v.copy()
f = f.reshape(xn, xn)
f = f.T
ax.plot_surface(xx0, xx1, f, color='blue', edgecolor='black', rstride=1, cstride=1,
ax.view_init(70, -110)
ax.set_xticklabels([])
ax.set_yticklabels([])
ax.set_zticklabels(v_ticks)
ax.set_title(title_str, fontsize=18)
M = 2
K = 3
xn = 15
x0 = np.linspace(X_range0[0], X_range0[1], xn)
x1 = np.linspace(X_range1[0], X_range1[1], xn)
xx0, xx1 = np.meshgrid(x0, x1)
x = np.c_[np.reshape(xx0, xn*xn, 1), np.reshape(xx1, xn*xn, 1)]
y, a, z, b = FNN(WV, M, K, x)
fig=plt.figure(1, figsize=(12, 9))
plt.subplots_adjust(left=0.075, bottom=0.05, right=0.95, top=0.95, wspace=0.4, hspace=0.
for m in range(M):
ax = fig.add_subplot(3, 4, 1+m*4, projection='3d')
show_activation3d(ax, b[:, m], [-10, 10], '$b_{0:d}$'.format(m))
ax = fig.add_subplot(3, 4, 2+m*4, projection='3d')
show_activation3d(ax, z[:, m], [0, 1], '$z_{0:d}$'.format(m))
for k in range(K):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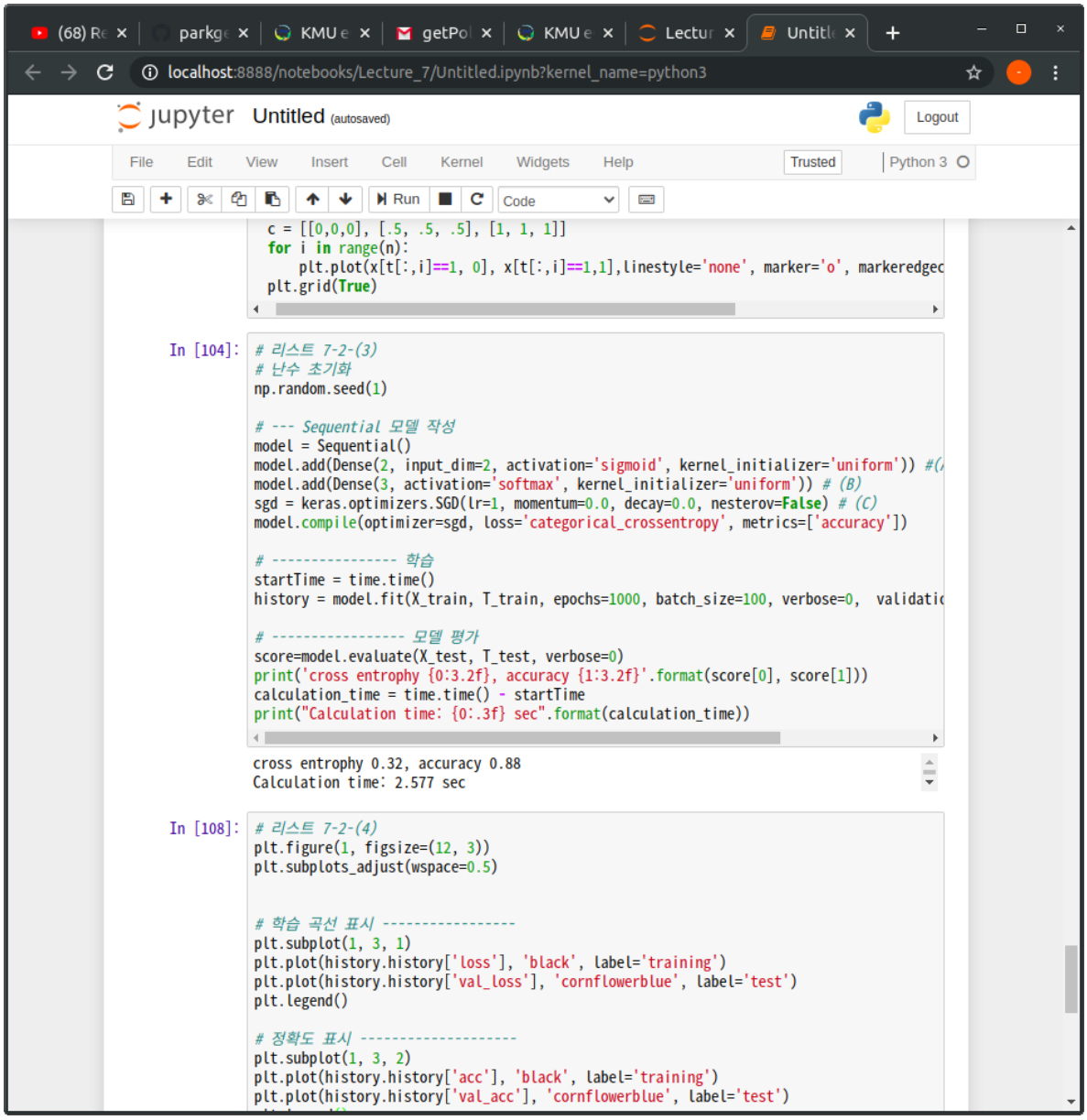
Code
ax = fig.add_subplot(3, 4, 1+m*4, projection='3d')
show_activation3d(ax, b[:, m], [-10, 10], '$b_{0:d}$'.format(m))
ax = fig.add_subplot(3, 4, 2+m*4, projection='3d')
show_activation3d(ax, z[:, m], [0, 1], '$z_{0:d}$'.format(m))
for k in range(K):
ax = fig.add_subplot(3, 4, 3+k*4, projection='3d')
show_activation3d(ax, a[:, k], [-5, 5], '$a_{0:d}$'.format(k))
ax = fig.add_subplot(3, 4, 4+k*4, projection='3d')
show_activation3d(ax, y[:, k], [0, 1], '$y_{0:d}$'.format(k))
plt.show()
In [91]:
%reset
Once deleted, variables cannot be recovered. Proceed (y/[n])? y
In [102]:
# 리스트 7-2-(1)
import numpy as np
import matplotlib.pyplot as plt
import time
np.random.seed(1) # (A)
import keras.optimizers
from keras.models import Sequential # (C)
from keras.layers.core import Dense, Activation # (D)
# 데이터 로드 ----------
outfile = np.load('class_data.npz')
X_train = outfile['X_train']
T_train = outfile['T_train']
X_test = outfile['X_test']
T_test = outfile['T_test']
X_range0 = outfile['X_range0']
X_range1 = outfile['X_range1']
In [103]:
리스트 7-2-(2)
데이터를 그리기 ----------
ef Show_data(x, t):
wk, n = t.shape
c = [[0,0,0], [.5, .5, .5], [1, 1, 1]]
for i in range(n):
plt.plot(x[t[:,i]==1, 0], x[t[:,i]==1,1],linestyle='none', marker='o', markeredgec
plt.grid(True)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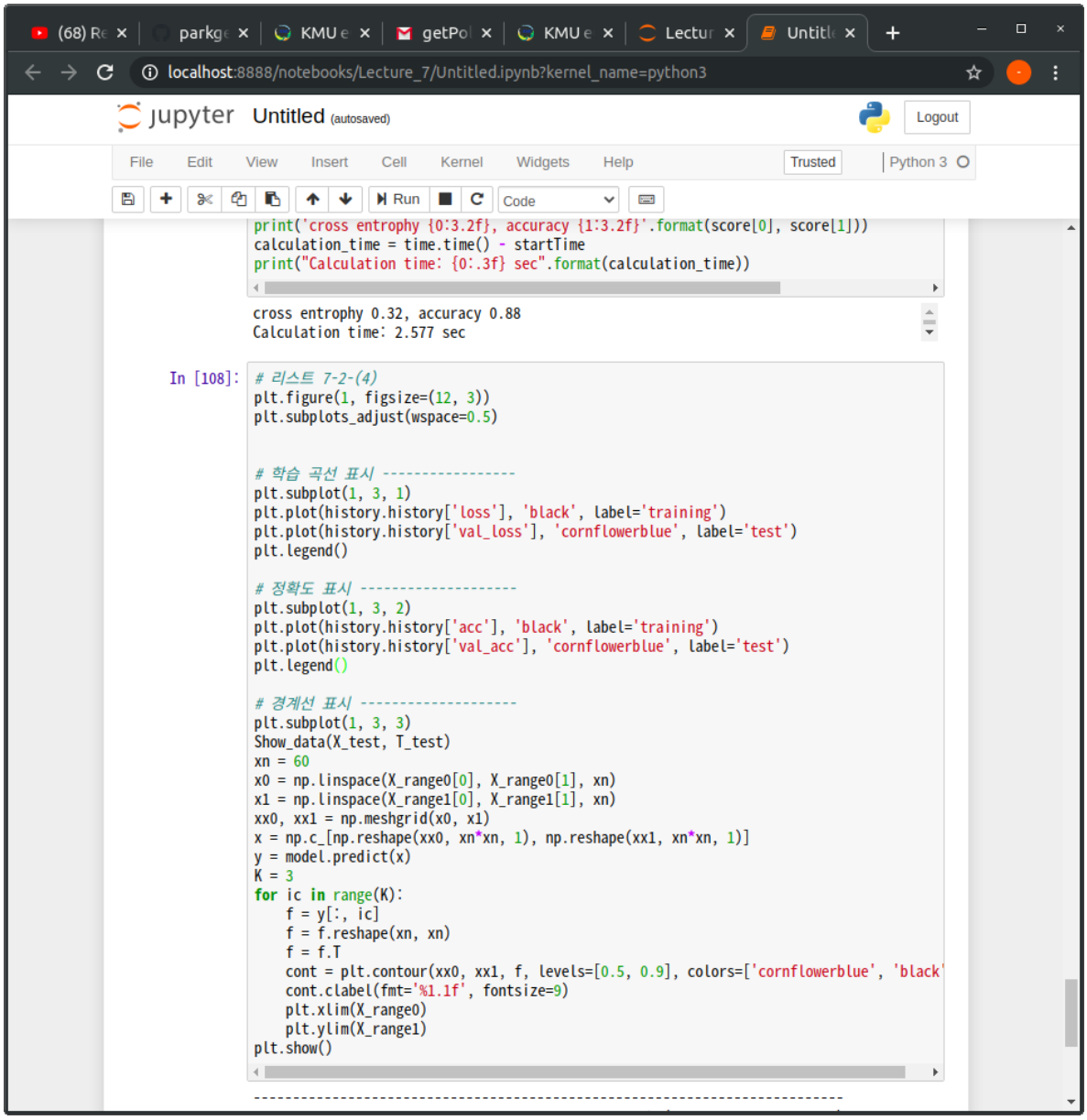
Python 3
Run
Code
c = [[0,0,0], [.5, .5, .5], [1, 1, 1]]
for i in range(n):
plt.plot(x[t[:,i]==1, 0], x[t[:,i]==1,1],linestyle='none', marker='o', markeredgec
plt.grid(True)
In [104]:
# 리스트 7-2-(3)
# 난수 초기화
np.random.seed(1)
# --- Sequential 모델 작성
model = Sequential()
model.add(Dense(2, input_dim=2, activation='sigmoid', kernel_initializer='uniform')) #(
model.add(Dense(3, activation='softmax', kernel_initializer='uniform')) # (B)
sgd = keras.optimizers.SGD(lr=1, momentum=0.0, decay=0.0, nesterov=False) # (C)
model.compile(optimizer=sgd, loss='categorical_crossentropy', metrics=['accuracy'])
# ---------- 학습
startTime = time.time()
history = model.fit(X_train, T_train, epochs=1000, batch_size=100, verbose=0, validatic
# ---------- 모델 평가
score=model.evaluate(X_test, T_test, verbose=0)
print('cross entrophy {0:3.2f}, accuracy {1:3.2f}'.format(score[0], score[1]))
calculation_time = time.time() - startTime
print("Calculation time: {0:.3f} sec".format(calculation_time))
cross entrophy 0.32, accuracy 0.88
Calculation time: 2.577 sec
In [108]:
# 리스트 7-2-(4)
plt.figure(1, figsize=(12, 3))
plt.subplots_adjust(wspace=0.5)
# 학습 곡선 표시 ----------
plt.subplot(1, 3, 1)
plt.plot(history.history['loss'], 'black', label='training')
plt.plot(history.history['val_loss'], 'cornflowerblue', label='test')
plt.legend()
# 정확도 표시 ----------
plt.subplot(1, 3, 2)
plt.plot(history.history['acc'], 'black', label='training')
plt.plot(history.history['val_acc'], 'cornflowerblue', label='test')




## 3. 소감

이번 과제를 하면서, 신경망 모델과 딥러닝의 기초를 하는 방법을 배울 수 있어서 좋았습니다. 또한, 여기저기서 많이 들었던 과정들을 직접해보니, 어렵기도 했지만 신기하고 좀 더 한층 이해할 수 있었던 시간을 가진 거 같아 기분이 좋았습니다.