In [1]:
```
#Implement the Continuous Bag of Words (CBOW) Model. Stages can be:
#a. Data preparation
#b. Generate training data
#c. Train model
#d. Output

import matplotlib.pyplot as plt
import seaborn as sns
import matplotlib as mpl
import matplotlib.pylab as pylab
import numpy as np
%matplotlib inline
```

```
C:\Users\Suraj\anaconda3\lib\site-packages\scipy\__init__.py:146: UserWarning: A NumPy version
>=1.16.5 and <1.23.0 is required for this version of SciPy (detected version 1.26.1
  warnings.warn(f"A NumPy version >={np_minversion} and <{np_maxversion}"
```

In [2]:
```
#Data Prepration
import re
```

In [3]:
```
sentences = """We are about to study the idea of a computational process.
Computational processes are abstract beings that inhabit computers.
As they evolve, processes manipulate other abstract things called data.
The evolution of a process is directed by a pattern of rules
called a program. People create programs to direct processes. In effect,
we conjure the spirits of the computer with our spells."""
```

In [4]:
```
# remove special characters
sentences = re.sub('[^A-Za-z0-9]+', ' ', sentences)

# remove 1 letter words
sentences = re.sub(r'(?:^| )\w(?:$| )', ' ', sentences).strip()

# lower all characters
sentences = sentences.lower()
```

In [5]:
```
#Vocabulary
words = sentences.split()
vocab = set(words)
```

In [6]:
```
vocab_size = len(vocab)
embed_dim = 10
context_size = 2
```

In [7]:
```
#Implementation
word_to_ix = {word: i for i, word in enumerate(vocab)}
ix_to_word = {i: word for i, word in enumerate(vocab)}
```

In [8]:
```
#Data bag
# data - [(context), target]

data = []
for i in range(2, len(words) - 2):
    context = [words[i - 2], words[i - 1], words[i + 1], words[i + 2]]
    target = words[i]
    data.append((context, target))
print(data[:5])
```

```
[(['we', 'are', 'to', 'study'], 'about'), (['are', 'about', 'study', 'the'], 'to'), (['about', 'to', 'the', 'idea'], 'study'), (['to', 'study', 'idea', 'of'], 'the'), (['study', 'the', 'of', 'computational'], 'idea')]
```

In [9]:
```
#embedding
embeddings =  np.random.random_sample((vocab_size, embed_dim))
```

In [10]:
```
#Linear Model
def linear(m, theta):
    w = theta
    return m.dot(w)
```

In [11]:
```
#Log softmax + NLLloss = Cross Entropy
def log_softmax(x):
    e_x = np.exp(x - np.max(x))
    return np.log(e_x / e_x.sum())
```

In [12]:
```
def NLLLoss(logs, targets):
    out = logs[range(len(targets)), targets]
    return -out.sum()/len(out)
```

In [13]:
```
def log_softmax_crossentropy_with_logits(logits,target):

    out = np.zeros_like(logits)
    out[np.arange(len(logits)),target] = 1

    softmax = np.exp(logits) / np.exp(logits).sum(axis=-1,keepdims=True)

    return (- out + softmax) / logits.shape[0]
```

In [14]:
```
#Forward Function
def forward(context_idxs, theta):
    m = embeddings[context_idxs].reshape(1, -1)
    n = linear(m, theta)
    o = log_softmax(n)

    return m, n, o
```

In [15]:
```
#Backward function
def backward(preds, theta, target_idxs):
    m, n, o = preds

    dlog = log_softmax_crossentropy_with_logits(n, target_idxs)
    dw = m.T.dot(dlog)

    return dw
```

In [16]:
```
#Optimize function
def optimize(theta, grad, lr=0.03):
    theta -= grad * lr
    return theta
```

In [17]:
```
#Genrate training data

theta = np.random.uniform(-1, 1, (2 * context_size * embed_dim, vocab_size))
```

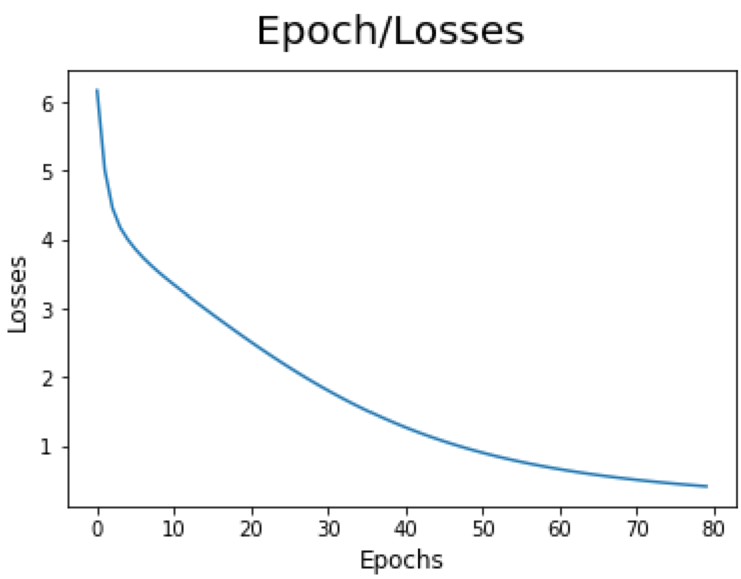
In [18]:
```
epoch_losses = {}

for epoch in range(80):

    losses =  []

    for context, target in data:
        context_idxs = np.array([word_to_ix[w] for w in context])
```

```
        preds = forward(context_idxs, theta)

        target_idxs = np.array([word_to_ix[target]])
        loss = NLLLoss(preds[-1], target_idxs)

        losses.append(loss)

        grad = backward(preds, theta, target_idxs)
        theta = optimize(theta, grad, lr=0.03)


    epoch_losses[epoch] = losses
```

In [19]:

```
#Analyze
#plot  loss / epochs
ix = np.arange(0,80)

fig = plt.figure()
fig.suptitle('Epoch/Losses', fontsize=20)
plt.plot(ix,[epoch_losses[i][0] for i in ix])
plt.xlabel('Epochs', fontsize=12)
plt.ylabel('Losses', fontsize=12)
```

Out[19]: Text(0, 0.5, 'Losses')



In [20]:

```
#Predict Function
def predict(words):
    context_idxs = np.array([word_to_ix[w] for w in words])
    preds = forward(context_idxs, theta)
    word = ix_to_word[np.argmax(preds[-1])]

    return word
```

In [21]:

```
# (['we', 'are', 'to', 'study'], 'about')
predict(['we', 'are', 'to', 'study'])
```

Out[21]: 'about'

In [22]:

```
def accuracy():
    wrong = 0

    for context, target in data:
        if(predict(context) != target):
            wrong += 1
```

```
    return (1 - (wrong / len(data)))
```

In [23]:
```
accuracy()
```

Out[23]: 1.0

In [24]:
```
#Output
predict(['processes', 'manipulate', 'things', 'study'])
```

Out[24]: 'they'

In [ ]: