Implement the Continuous Bag of Words (CBOW) Model. Stages can be:

a. Data preparation
b. Generate training data
c. Train model
d. Output

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

[2]:
```
data = """Deep learning (also known as deep structured learning) is part of a broader family of machine learning methods based on artificial neural networ
data
```

[2]:
```
'Deep learning (also known as deep structured learning) is part of a broader family of machine learning methods based on artificial neural networks with representation learning. Learning can be supervised, semi-supervised or unsupervised. Deep-learning architectures such as deep neural networks, deep belief networks, deep reinforcement learning, recurrent neural networks, convolutional neural networks and Transformers have been applied to fields including computer vision, speech recognition, natural language processing, machine translation, bioinformatics, drug design, medical image analysis, climate science, material inspection and board game programs, where they have produced results comparable to and in some cases surpassing human expert performance.'
```

[3]:
```
sentences = data.split('.')
sentences
```

[3]:
```
['Deep learning (also known as deep structured learning) is part of a broader family of machine learning methods based on artificial neural networks with representation learning',
 ' Learning can be supervised, semi-supervised or unsupervised',
 ' Deep-learning architectures such as deep neural networks, deep belief networks, deep reinforcement learning, recurrent neural networks, convolutional neural networks and Transformers have been applied to fields including computer vision, speech recognition, natural language processing, machine translation, bioinformatics, drug design, medical image analysis, climate science, material inspection and board game programs, where they have produced results comparable to and in some cases surpassing human expert performance',
 '']
```

[4]:
```
clean_sent=[]
for sentence in sentences:
    if sentence=="":
        continue
    sentence = re.sub('[^A-Za-z0-9]+', ' ', (sentence))
    sentence = re.sub(r'(?:^| )\w (?:$| )', ' ', (sentence)).strip()
    sentence = sentence.lower()
    clean_sent.append(sentence)

clean_sent
```

[4]:
```
['deep learning also known as deep structured learning is part of a broader family of machine learning methods based on artificial neural networks with representation learning',
 'learning can be supervised semi supervised or unsupervised',
 'deep learning architectures such as deep neural networks deep belief networks deep reinforcement learning recurrent neural networks convolutional neural networks and transformers have been applied to fields including computer vision speech recognition natural language processing machine translation bioinformatics drug design medical image analysis climate science material inspection and board game programs where they have produced results comparable to and in some cases surpassing human expert performance']
```

[5]:
```
from tensorflow.keras.preprocessing.text import Tokenizer
```

[6]:
```
tokenizer = Tokenizer()
tokenizer.fit_on_texts(clean_sent)
sequences = tokenizer.texts_to_sequences(clean_sent)
print(sequences)
```

```
[[2, 1, 12, 13, 6, 2, 14, 1, 15, 16, 7, 17, 18, 19, 7, 8, 1, 20, 21, 22, 23, 4, 3, 24, 25, 1], [1, 26, 27, 9, 28, 9, 29, 30], [2, 1, 31, 32, 6, 2, 4, 3, 2, 33, 3, 2, 34, 1, 35, 4, 3, 36, 4, 3, 5, 37, 10, 38, 39, 11, 40, 41, 42, 43, 44, 45, 46, 47, 48, 8, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 5, 60, 61, 62, 63, 64, 10, 65, 66, 67, 11, 5, 68, 69, 70, 71, 72, 73, 74]]
```

[7]:
```
index_to_word = {}
word_to_index = {}

for i, sequence in enumerate(sequences):
#     print(sequence)
    word_in_sentence = clean_sent[i].split()
#     print(word_in_sentence)

    for j, value in enumerate(sequence):
        index_to_word[value] = word_in_sentence[j]
        word_to_index[word_in_sentence[j]] = value

print(index_to_word, "\n")
print(word_to_index)
```

```
{2: 'deep', 1: 'learning', 12: 'also', 13: 'known', 6: 'as', 14: 'structured', 15: 'is', 16: 'part', 7: 'of', 17: 'a', 18: 'broader', 19: 'family', 8: 'machine', 20: 'methods', 21: 'based', 22: 'on', 23: 'artificial', 4: 'neural', 3: 'networks', 24: 'with', 25: 'representation', 26: 'can', 27: 'be', 9: 'supervised', 28: 'semi', 29: 'or', 30: 'unsupervised', 31: 'architectures', 32: 'such', 33: 'belief', 34: 'reinforcement', 35: 'recurrent', 36: 'convolutional', 5: 'and', 37: 'transformers', 10: 'have', 38: 'been', 39: 'applied', 11: 'to', 40: 'fields', 41: 'including', 42: 'computer', 43: 'vision', 44: 'speech', 45: 'recognition', 46: 'natural', 47: 'language', 48: 'processing', 49: 'translation', 50: 'bioinformatics', 51: 'drug', 52: 'design', 53: 'medical', 54: 'image', 55: 'analysis', 56: 'climate', 57: 'science', 58: 'material', 59: 'inspection', 60: 'board', 61: 'game', 62: 'programs', 63: 'where', 64: 'they', 65: 'produced', 66: 'results', 67: 'comparable', 68: 'in', 69: 'some', 70: 'cases', 71: 'surpassing', 72: 'human', 73: 'expert', 74: 'performance'}

{'deep': 2, 'learning': 1, 'also': 12, 'known': 13, 'as': 6, 'structured': 14, 'is': 15, 'part': 16, 'of': 7, 'a': 17, 'broader': 18, 'family': 19, 'machine': 8, 'methods': 20, 'based': 21, 'on': 22, 'artificial': 23, 'neural': 4, 'networks': 3, 'with': 24, 'representation': 25, 'can': 26, 'be': 27, 'supervised': 9, 'semi': 28, 'or': 29, 'unsupervised': 30, 'architectures': 31, 'such': 32, 'belief': 33, 'reinforcement': 34, 'recurrent': 35, 'convolutional': 36, 'and': 5, 'transformers': 37, 'have': 10, 'been': 38, 'applied': 39, 'to': 11, 'fields': 40, 'including': 41, 'computer': 42, 'vision': 43, 'speech': 44, 'recognition': 45, 'natural': 46, 'language': 47, 'processing': 48, 'translation': 49, 'bioinformatics': 50, 'drug': 51, 'design': 52, 'medical': 53, 'image': 54, 'analysis': 55, 'climate': 56, 'science': 57, 'material': 58, 'inspection': 59, 'board': 60, 'game': 61, 'programs': 62, 'where': 63, 'they': 64, 'produced': 65, 'results': 66, 'comparable': 67, 'in': 68, 'some': 69, 'cases': 70, 'surpassing': 71, 'human': 72, 'expert': 73, 'performance': 74}
```

[21]:
```python
vocab_size = len(tokenizer.word_index) + 1
# emb_size = 10
context_size = 2

contexts = []
targets = []

for sequence in sequences:
    for i in range(context_size, len(sequence) - context_size):
        target = sequence[i]
        context = [sequence[i - 2], sequence[i - 1], sequence[i + 1], sequence[i + 2]]
#         print(context)
        contexts.append(context)
        targets.append(target)
print(contexts, "\n")
print(targets)
```

```
[[2, 1, 13, 6], [1, 12, 6, 2], [12, 13, 2, 14], [13, 6, 14, 1], [6, 2, 1, 15], [2, 14, 15, 16], [14, 1, 16, 7], [1, 15, 7, 17], [15, 16, 17, 18], [16, 7,
18, 19], [7, 17, 19, 7], [17, 18, 7, 8], [18, 19, 8, 1], [19, 7, 1, 20], [7, 8, 20, 21], [8, 1, 21, 22], [1, 20, 22, 23], [20, 21, 23, 4], [21, 22, 4,
3], [22, 23, 3, 24], [23, 4, 24, 25], [4, 3, 25, 1], [1, 26, 9, 28], [26, 27, 28, 9], [27, 9, 9, 29], [9, 28, 29, 30], [2, 1, 32, 6], [1, 31, 6, 2], [31,
32, 2, 4], [32, 6, 4, 3], [6, 2, 3, 2], [2, 4, 2, 33], [4, 3, 33, 3], [3, 2, 3, 2], [2, 33, 2, 34], [33, 3, 34, 1], [3, 2, 1, 35], [2, 34, 35, 4], [34,
1, 4, 3], [1, 35, 3, 36], [35, 4, 36, 4], [4, 3, 4, 3], [3, 36, 3, 5], [36, 4, 5, 37], [4, 3, 37, 10], [3, 5, 10, 38], [5, 37, 38, 39], [37, 10, 39, 11],
[10, 38, 11, 40], [38, 39, 40, 41], [39, 11, 41, 42], [11, 40, 42, 43], [40, 41, 43, 44], [41, 42, 44, 45], [42, 43, 45, 46], [43, 44, 46, 47], [44, 45,
47, 48], [45, 46, 48, 8], [46, 47, 8, 49], [47, 48, 49, 50], [48, 8, 50, 51], [8, 49, 51, 52], [49, 50, 52, 53], [50, 51, 53, 54], [51, 52, 54, 55], [52,
53, 55, 56], [53, 54, 56, 57], [54, 55, 57, 58], [55, 56, 58, 59], [56, 57, 59, 5], [57, 58, 5, 60], [58, 59, 60, 61], [59, 5, 61, 62], [5, 60, 62, 63],
[60, 61, 63, 64], [61, 62, 64, 10], [62, 63, 10, 65], [63, 64, 65, 66], [64, 10, 66, 67], [10, 65, 67, 11], [65, 66, 11, 5], [66, 67, 5, 68], [67, 11, 6
8, 69], [11, 5, 69, 70], [5, 68, 70, 71], [68, 69, 71, 72], [69, 70, 72, 73], [70, 71, 73, 74]]

[12, 13, 6, 2, 14, 1, 15, 16, 7, 17, 18, 19, 7, 8, 1, 20, 21, 22, 23, 4, 3, 24, 27, 9, 28, 9, 31, 32, 6, 2, 4, 3, 2, 33, 3, 2, 34, 1, 35, 4, 3, 36, 4, 3,
5, 37, 10, 38, 39, 11, 40, 41, 42, 43, 44, 45, 46, 47, 48, 8, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 5, 60, 61, 62, 63, 64, 10, 65, 66, 67, 11, 5, 6
8, 69, 70, 71, 72]
```

[22]:
```python
#printing features with target
for i in range(5):
    words = []
    target = index_to_word.get(targets[i])
    for j in contexts[i]:
        words.append(index_to_word.get(j))
    print(words," -> ", target)
```

```
['deep', 'learning', 'known', 'as']  ->  also
['learning', 'also', 'as', 'deep']  ->  known
['also', 'known', 'deep', 'structured']  ->  as
['known', 'as', 'structured', 'learning']  ->  deep
['as', 'deep', 'learning', 'is']  ->  structured
```

[23]:
```python
# Convert the contexts and targets to numpy arrays
X = np.array(contexts)
Y = np.array(targets)
```

[24]:
```python
# print(X)
```

[25]:
```python
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Embedding, Lambda
```

[26]:
```python
model = Sequential([
    Embedding(input_dim=vocab_size, output_dim=emb_size, input_length=2*context_size),
    Lambda(lambda x: tf.reduce_mean(x, axis=1)),
    Dense(256, activation='relu'),
    Dense(512, activation='relu'),
    Dense(vocab_size, activation='softmax')
])
```

```
C:\Users\ASUS\AppData\Roaming\Python\Python312\site-packages\keras\src\layers\core\embedding.py:90: UserWarning: Argument `input_length` is deprecated. J
ust remove it.
  warnings.warn(
```

[27]:
```python
model.compile(loss='sparse_categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
```

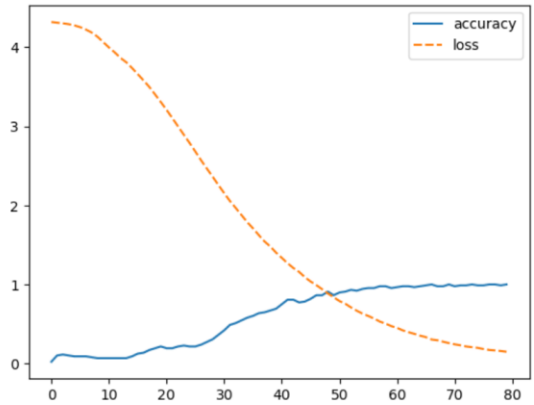
[28]:
```python
history = model.fit(X, Y, epochs=80)
```

```
Epoch 1/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 14ms/step - accuracy: 0.0153 - loss: 4.3180
Epoch 2/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.1058 - loss: 4.3105
Epoch 3/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 1ms/step - accuracy: 0.1428 - loss: 4.3024
Epoch 4/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.1214 - loss: 4.2909
Epoch 5/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - accuracy: 0.0845 - loss: 4.2765
Epoch 6/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.1001 - loss: 4.2567
```

```
Epoch 68/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9886 - loss: 0.2839
Epoch 69/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9808 - loss: 0.2774
Epoch 70/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 1.0000 - loss: 0.2379
Epoch 71/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9808 - loss: 0.2463
Epoch 72/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9904 - loss: 0.2259
Epoch 73/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9826 - loss: 0.2120
Epoch 74/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 1.0000 - loss: 0.2101
Epoch 75/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - accuracy: 0.9943 - loss: 0.1889
Epoch 76/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - accuracy: 0.9904 - loss: 0.1689
Epoch 77/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 1.0000 - loss: 0.1769
Epoch 78/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 1.0000 - loss: 0.1737
Epoch 79/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - accuracy: 0.9904 - loss: 0.1636
Epoch 80/80
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 1.0000 - loss: 0.1634
```

[29]:
```
import seaborn as sns
sns.lineplot(model.history.history)
```

[29]: <Axes: >



[30]:
```
# from sklearn.decomposition import PCA

# embeddings = model.get_weights()[0]

# pca = PCA(n_components=2)
# reduced_embeddings = pca.fit_transform(embeddings)
```

[31]:
```
print("'Deep learning (also known as deep structured learning) is part of a broader family of machine learning methods based on artificial neural networks
```

```
'Deep learning (also known as deep structured learning) is part of a broader family of machine learning methods based on artificial neural networks with
representation learning. Learning can be supervised, semi-supervised or unsupervised. Deep-learning architectures such as deep neural networks, deep beli
ef networks, deep reinforcement learning, recurrent neural networks, convolutional neural networks and Transformers have been applied to fields including
computer vision, speech recognition, natural language processing, machine translation, bioinformatics, drug design, medical image analysis, climate scien
ce, material inspection and board game programs, where they have produced results comparable to and in some cases surpassing human expert performance.
```

[32]:
```
# test model: select some sentences from above paragraph
test_sentenses = [
    "known as structured learning",
    "transformers have applied to",
    "where they produced results",
    "cases surpassing expert performance",
    "comparable to in some",
    "some cases surpassing human"
]
```

```
[33]: for sent in test_sentenses:
    test_words = sent.split(" ")
#     print(test_words)
    x_test =[]
    for i in test_words:
        x_test.append(word_to_index.get(i))
    x_test = np.array([x_test])
#     print(x_test)

    pred = model.predict(x_test)
    pred = np.argmax(pred[0])
    print("pred ", test_words, "\n=", index_to_word.get(pred),"\n\n")
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 86ms/step
pred  ['known', 'as', 'structured', 'learning']
= deep


1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step
pred  ['transformers', 'have', 'applied', 'to']
= been


1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step
pred  ['where', 'they', 'produced', 'results']
= have


1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step
pred  ['cases', 'surpassing', 'expert', 'performance']
= human


1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 30ms/step
pred  ['comparable', 'to', 'in', 'some']
= and


1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 30ms/step
pred  ['some', 'cases', 'surpassing', 'human']
= surpassing
```